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Biological Characteristics of the Sport Harvest of Marine Groundfishes in Southcentral Alaska, 1991

by

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Alaska Department of Fish and Game

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BIOLOGICAL CHARACTERISTICS OF THE SPORT HARVEST OF MARINE GROUNDFISHES IN SOUTHCENTRAL ALASKA, 1991[1]

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Scott C. Meyer

Alaska Department of Fish and Game
Division of Sport Fish
Anchorage, Alaska

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ABSTRACT

Age, length, and sex data were collected from 3,134 rockfish, 820 lingcod, and 3,317 halibut harvested by sport anglers at Deep Creek, Homer, Seward, Whittier, and Valdez in 1991 (some data were also collected at Valdez in 1990). Twenty species of rockfish were harvested by sport anglers, but black rockfish *Sebastes melanops* and yelloweye rockfish *Sebastes ruberrimus* made up the vast majority at most ports. Black rockfish were 8-37 years old and 35-69 centimeters long (total length). Age and length composition differed significantly between ports. Yelloweye rockfish were 9-92 years old and 26-86 centimeters long. Yelloweye rockfish harvested from Prince William Sound (Whittier and Valdez) were younger, smaller, and grew more slowly than fish from the Gulf of Alaska (Homer and Seward). Total instantaneous mortality rates ranged from 0.16 to 0.51 for black rockfish, and from 0.05 to 0.09 for yelloweye and quillback rockfish. Mortality rates may have been overestimated because of size selectivity of the sport harvest. Lingcod were 4-23 years old and 47-145 centimeters long. Age and length composition differed between ports. Trends in lingcod age and length composition since 1987 suggest declining recruitment and potential collapse of the rapidly developing fishery in Gulf of Alaska waters near Seward. Harvested halibut were 3-22 years old and were fully recruited to the sport fishery by age 8. Female halibut made up 60%-85% of the sport harvest, depending on location. Seasonal trends in age and size composition observed in some fisheries suggested spring onshore and fall offshore movements of large halibut. Conservative management of rockfishes and lingcod is recommended given the current knowledge of movements, abundance, and exploitation. Fish sampling and tagging are recommended that are independent of the sport and commercial harvests.

KEY WORDS: Rockfish, *Sebastes*, yelloweye rockfish, *Sebastes ruberrimus*, black rockfish, *Sebastes melanops*, quillback rockfish, *Sebastes maliger*, lingcod, *Ophiodon elongatus*, Pacific halibut, *Hippoglossus stenolepis*, Deep Creek, Homer, Seward, Whittier, Valdez, Alaska, Gulf of Alaska, Prince William Sound, Cook Inlet, Kachemak Bay, Resurrection Bay, sport fishery, harvest, species composition, age, length, survival, growth, stock assessment.

INTRODUCTION

The marine sport fisheries in Southcentral Alaska (Figure 1) are diverse and growing steadily in popularity. Sport fishing effort in marine waters between Cape St. Elias and Adak grew from 199,450 angler days in 1980 to over 444,000 angler days in 1990 (Mills 1979-1991). This effort represented 54% of the statewide saltwater effort and 18% of the total statewide effort for all species in 1990 (Figure 2, Appendix A1). Kenai Peninsula coastal waters, including Kachemak Bay, lower Cook Inlet, Resurrection Bay, and the Gulf of Alaska, accounted for nearly two-thirds of the Southcentral Alaska effort. The major ports of sport groundfish landings in Southcentral Alaska are Valdez, Whittier, Seward, Homer, Deep Creek, and Kodiak (Figure 1).

Although most angling effort is directed at salmon, groundfishes represent a major fraction of the harvest. The principal groundfishes harvested in the sport fishery include Pacific halibut *Hippoglossus stenolepis*, numerous rockfishes *Sebastes*, and lingcod *Ophiodon elongatus*. Pacific halibut (halibut hereafter) were the primary groundfish harvested and made up over 39% (in number) of the 1990 Southcentral Alaska saltwater finfish harvest. By comparison, rockfishes made up 8% (in number) of the region-wide saltwater harvest. Rockfish and lingcod are most popular in the Seward-based fishery, where rockfish made up 25% and lingcod made up 9% of the saltwater finfish harvest in 1990 (Mills 1991). Other species harvested in unknown numbers include Pacific cod *Gadus macrocephalus*, arrowtooth flounder *Atheresthes stomias*, greenlings *Hexagrammos*, and Irish lords *Hemilepidotus*.

Sport harvests of groundfish are generally increasing in Southcentral Alaska. Halibut harvest rose steadily from 17,000 fish in 1977 to 181,000 fish in 1990, representing 60%-84% of the statewide harvest (Figure 3, Appendix A2; Mills 1979-1991). Sport rockfish harvests have been variable but generally increased from 22,000 fish in 1977 to 128,000 fish in 1988 (Figure 4). Rockfish harvests declined after 1988, with 63,000 fish harvested in 1990. This decline was likely due in part to a reduction in the rockfish daily bag limit from 10 to 5 fish effective in 1989. Fisheries in Southcentral Alaska have accounted for 39%-71% of the statewide rockfish harvest since 1977 (Appendix A3; Mills 1979-1991). Lingcod harvest estimates are available only for the Seward fishery, and show a strong increasing trend from 2,142 fish in 1987 to 6,945 fish in 1990 (Table 1). The sport fishery has accounted for the vast majority of lingcod harvest in state waters of the Gulf of Alaska since 1987. Current daily bag limits are two halibut, two lingcod, and five rockfish of any size per person throughout most of Southcentral Alaska.

The economic value of recreational groundfish fisheries is often unrecognized. For instance, anglers spent over $18 million to participate in the 1986 halibut fishery in Southcentral Alaska, an amount equal to that spent fishing for chinook salmon *Oncorhynchus tshawytscha* in the Kenai River (Jones and Stokes 1987). Two-thirds of the expenditures were by resident anglers. In addition, anglers indicated that they would be willing to spend an additional $25 million in order to ensure the availability of halibut fishing opportunities. Economic data are not available specifically for recreational rockfish or lingcod fisheries.

Although available information confirms that the groundfish fishery is growing in popularity and economically important, little is known of the biological

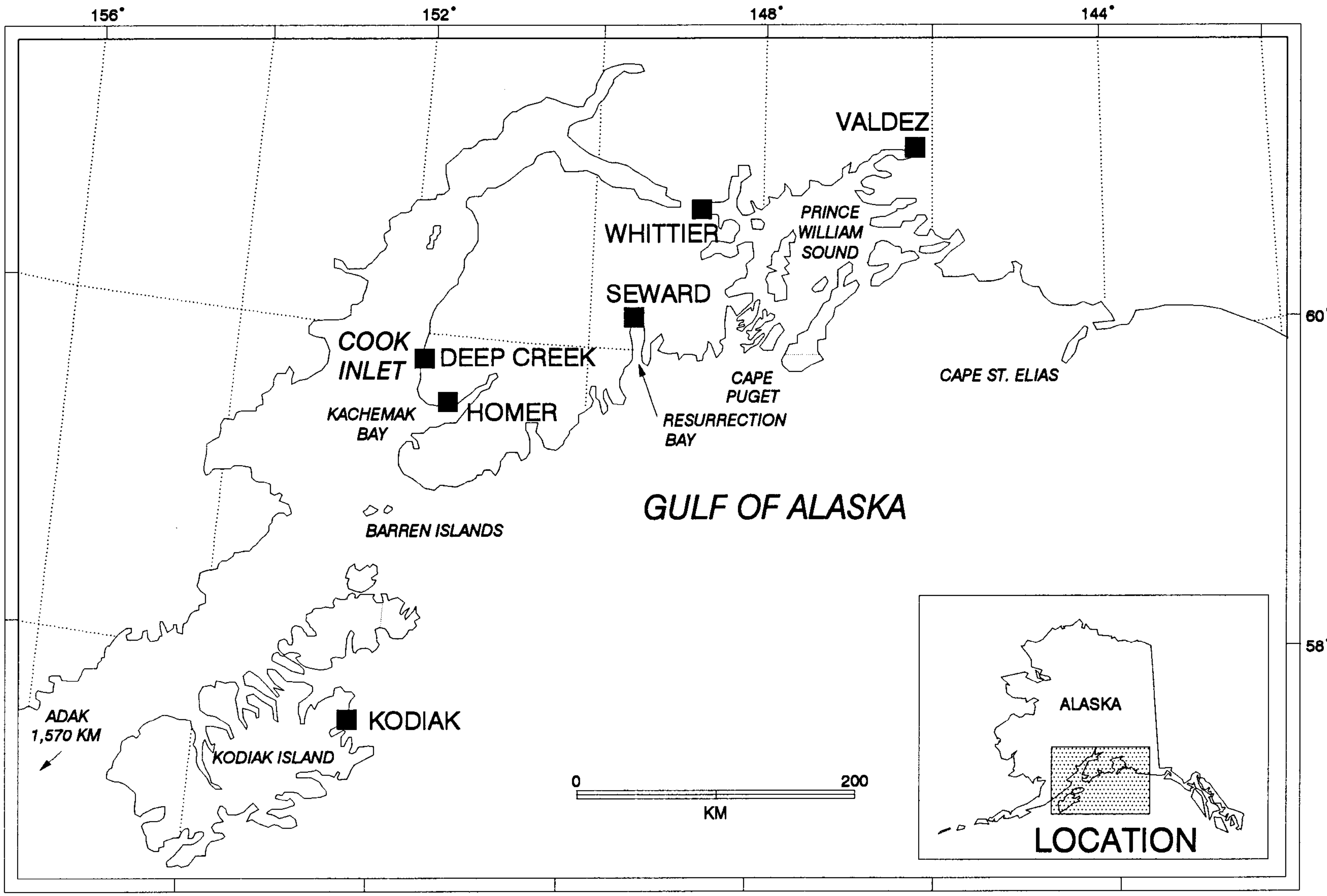

Figure 1. Waters and major ports of sport groundfish landings in Southcentral Alaska.

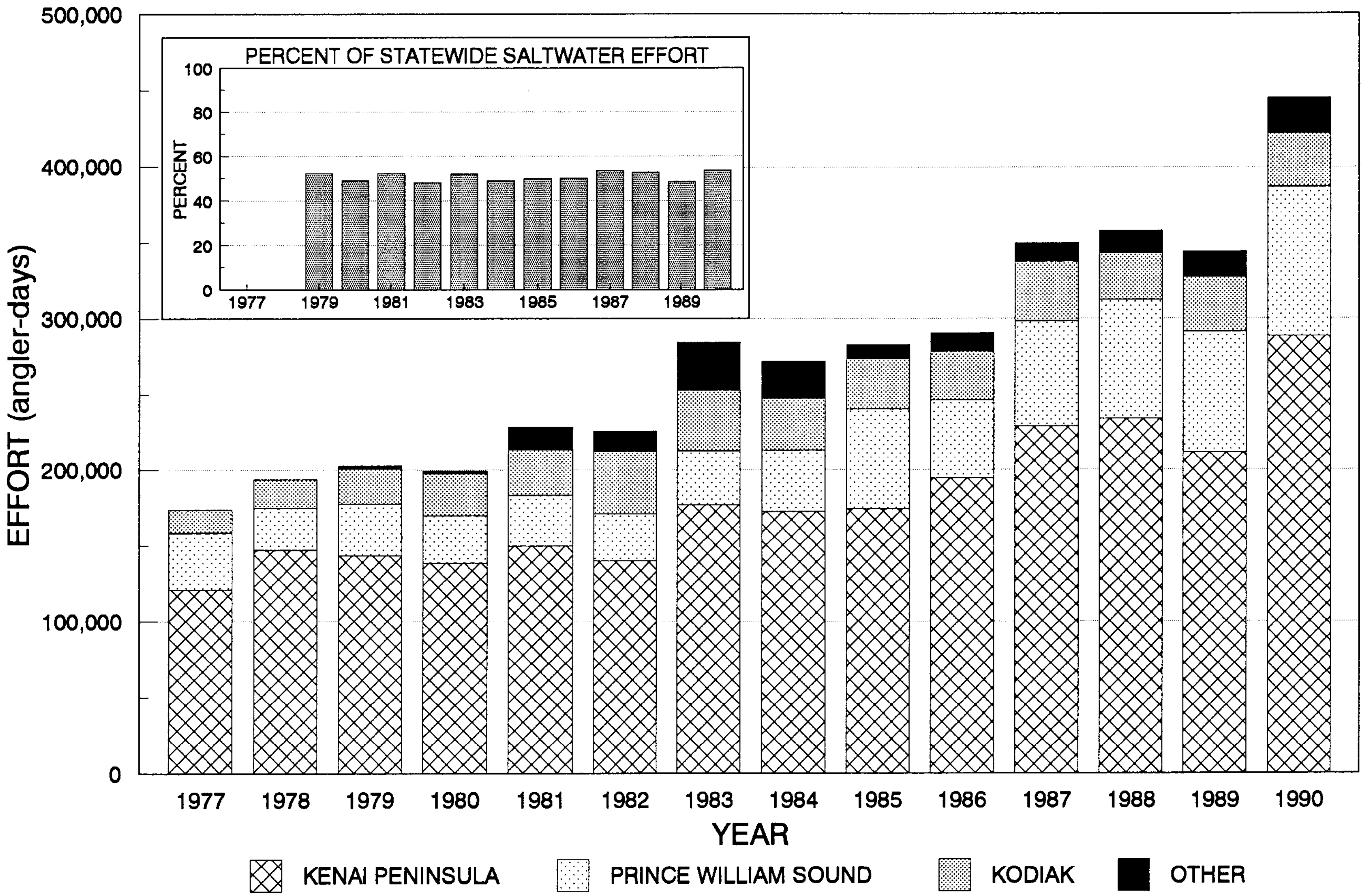

Figure 2. Estimated angler effort in marine waters of Southcentral Alaska, 1977-1990 (Mills 1979-1991). The inset shows that about 50% of the statewide marine angler effort is expended in Southcentral Alaska. "Kenai Peninsula" includes marine waters from Cape Puget to Portage, and "Other" includes northern and western Cook Inlet, and marine waters adjacent to the Alaska Peninsula.

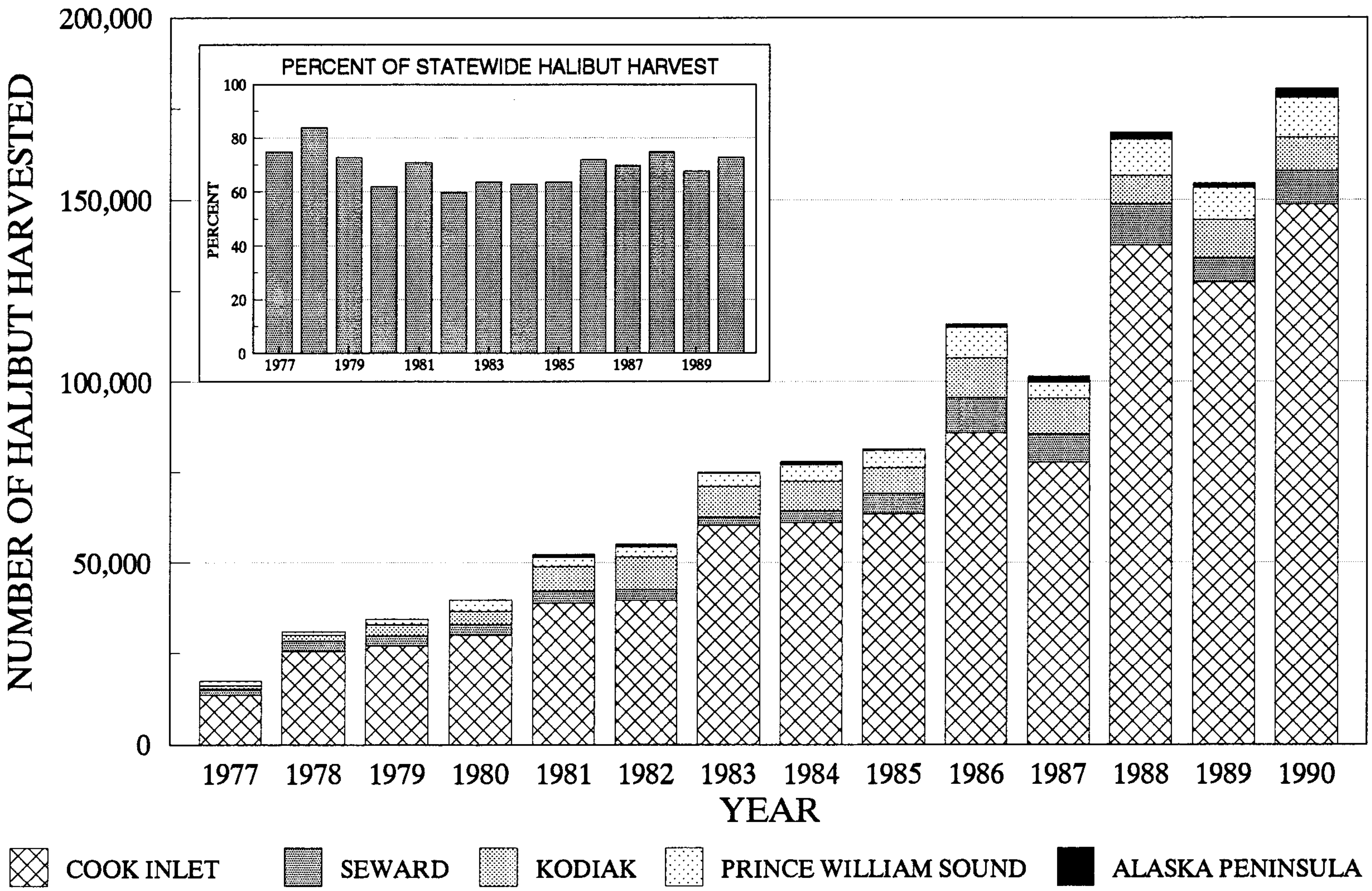

Figure 3. Estimated halibut harvest by sport anglers in Southcentral Alaska, 1977-1990 (Mills 1979-1991). The inset shows that 60%-84% of the statewide halibut harvest has been from Southcentral Alaska.

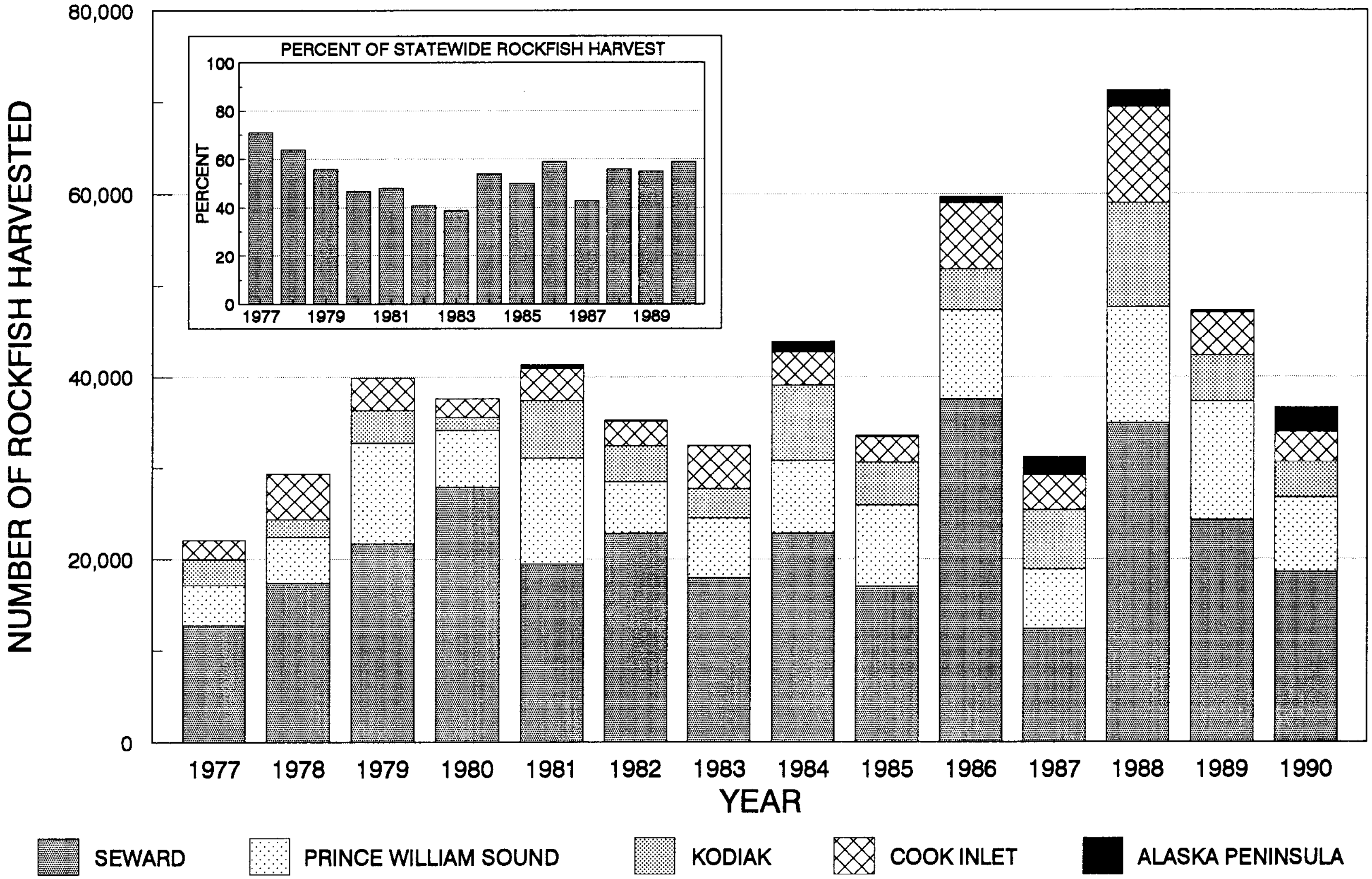

Figure 4. Estimated harvest of all rockfishes by sport anglers in Southcentral Alaska, 1977-1990 (Mills 1979-1991). The inset shows that 39%-71% of the statewide rockfish harvest has been from Southcentral Alaska.

Table 1. Estimated sport and commercial harvests of lingcod in Gulf of Alaska waters adjacent to Seward, Alaska, 1987-1991.

Year	Commercial (Pounds[a])	Sport Number	Sport Pounds[b]	Total Pounds	Percent Sport
1987	1,631	2,142[c]	28,272	29,903	94.5
1988	3,574	4,189[d]	67,278	70,852	95.0
1989	1,419	5,505[d]	74,506	75,925	98.1
1990	251	6,945[e]	106,780	107,031	99.8
1991	2,944	NA[f]	NA[f]	NA[f]	NA[f]

[a] Round weight; source: Bechtol 1992. Includes all state waters between Harris point (149#56' W.) and Cape Fairfield (148#50' W.).

[b] Round weight of the sport harvest was calculated as (number x mean weight) for each year. Mean weights were estimated for each year using Mean = $(\Sigma w_i)/n$, where the w_i are the predicted weights of all n individual fish sampled. Weights were predicted using the relationship $\ln w(kg) = -10.4934 + 2.7607 [\ln \text{total length (cm)}]$ calculated from 1991 Seward data.

[c] Source: Vincent-Lang et al. 1988.

[d] Source: Carlon and Vincent Lang 1989, 1990. A count of lingcod harvested by the U.S. Army Recreation Camp was not available for 1988. The military harvest was therefore the sum of a count from the U.S. Air Force Camp and an estimate of the Army Camp harvest. The Army Camp harvest was estimated as the product of the reported effort and the mean harvest per unit effort in subsequent years.

[e] Source: M. J. Mills, Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services, personal communication.

[f] NA - data not available until late 1992.

characteristics or stock status of many of the primary species in the harvest. Halibut are the best understood species, having been monitored and managed by international treaty since 1924 (IPHC 1987). Even so, limited data are available to describe biological characteristics of the sport harvest. Some species, age, and size data have been collected from rockfish and lingcod by the Alaska Department of Fish and Game (ADF&G) in the Seward area since 1981 (Morrison 1981, 1982; Vincent-Lang et al. 1988; Carlon and Vincent-Lang 1989, 1990; Vincent-Lang 1991), but very little was known of species, age, size, or sex composition of the sport harvests in Prince William Sound, Kachemak Bay, and lower Cook Inlet.

This project was initiated in 1991 to provide some of the basic data needed to manage these growing fisheries. Concern was initially focused on rockfish and lingcod stocks because of growing harvests and their history of over-exploitation by sport and commercial fisheries (Francis 1985, Bargmann 1985, Bracken 1986, Schwan 1989, Culver et al. 1991, Richards and Hand 1991). Rockfish and lingcod have low rates of production and are inherently susceptible to overharvest. Most rockfishes are long-lived and slow-growing fish that are not mature until 5-15 years old. While lingcod grow faster and mature earlier, recruitment is reported to be highly variable from year to year (Bargmann 1982). Most nearshore rockfishes as well as lingcod are territorial for at least portions of the year, and inhabit rocky areas that are easily found and exploited by anglers. Localized reductions in abundance can occur over relatively short periods of time. Because these fishes have low rates of production, recovery from overharvest may take many years.

Although halibut are primarily managed by the International Pacific Halibut Commission (IPHC) and the North Pacific Fishery Management Council, most of their data come from commercial and test fisheries. Initiation of this study allowed the ADF&G to provide these agencies with needed age, size, and sex information from the growing sport fishery that accounted for about 11% of all halibut removals in Southcentral Alaska in 1991 (P. Sullivan, IPHC, personal communication). The IPHC intends to begin incorporating sport harvest information from state and federal agencies into their stock assessment to estimate exploitable biomass and set appropriate catch limits (R. Trumble, IPHC, personal communication).

The goal of this project was to monitor the biological characteristics of rockfishes, lingcod, and halibut landed by sport anglers at Valdez, Whittier, Seward, Deep Creek, and Homer. Specific objectives in 1991 were to:

Rockfishes:

1. Estimate the species composition of the sport harvest landed at each port,

2. Estimate the age, sex, and size composition of the most abundant species in the harvest at each port (generally black rockfish and yelloweye rockfish),

3. Estimate the mean length at age of the most abundant species in the harvest at each port (generally black rockfish and yelloweye rockfish),

4. Estimate the mortality rates of the most abundant species in the harvest at Seward and Valdez (generally black rockfish and yelloweye rockfish),

Lingcod:

5. Estimate the age, sex, and size composition of fish landed at each port,

6. Estimate the mean length at age of males and females landed at each port,

7. Estimate the annual survival rate of lingcod in the area fished by the Seward-based sport fleet,

Halibut:

8. Estimate the age, sex, and size composition of fish landed at each port,

9. Estimate the mean length at age of males and females landed at all ports.

An additional task was to estimate the spatial distribution of groundfish fishing effort by the fleets at each port.

METHODS

Study Design

Technicians were stationed at Valdez, Whittier, Seward, and Homer in 1991. The technician stationed at Homer also sampled halibut at the Deep Creek boat landing. These locations provided samples of groundfish harvest from Prince William Sound, nearshore waters of the Gulf of Alaska between Cape Puget and the Barren Islands, Kachemak Bay, and lower Cook Inlet (Figure 1) In 1990, a technician was also stationed at Valdez to sample groundfish and examine pink salmon *O. gorbuscha* and coho salmon *O. kisutch* for coded wire tags. This report will present the 1990 Valdez groundfish data as well.

Sampling was conducted for an average of 7.5 hours per day, 5 days per week at all ports except Deep Creek. The Deep Creek boat landing was sampled at the rate of 7-10 days per month. All weekends and 3 weekdays per week were worked. Technicians intercepted whole fish or cleaned fish carcasses at the cleaning stations in the boat harbors. Designated barrels were placed near the cleaning stations or boat ramps to collect fish carcasses when the technician was busy or off-duty. Signs were posted in each harbor explaining the sampling program and requesting angler cooperation.

Rockfish and lingcod were given the highest sampling priority. Length, sex, and age data were collected from every rockfish and lingcod landed during work shifts at Valdez, Whittier, and Homer. At Seward, the port of greatest rockfish and lingcod landings, the number of rockfish and lingcod landed consistently exceeded the number that could be sampled in a day. Therefore, fish were sampled systematically (e.g. every fifth fish) to minimize bias. At all ports, halibut were not sampled until all available rockfish and lingcod were sampled. At Whittier, the number of halibut landed was small enough that data were collected from practically all fish landed during work shifts. At all other ports, the number of halibut landed each day usually exceeded the number that could be sampled. When this occurred, halibut were sampled systematically to avoid sampling bias, but daily sample sizes were probably not proportional to daily harvest. Technicians attempted to sample fish from private, charter, and military anglers in proportion to the number landed by each group.

Although the work schedule at Valdez in 1990 was very similar to 1991, sampling priorities were organized differently. In addition to groundfish sampling, pink salmon and coho salmon were examined for coded wire tags as part of another project. Since a considerable amount of time was spent examining salmon, monthly sample sizes for groundfish were not assumed to be proportional to harvest.

Rockfishes were identified to species using Kramer and O'Connell (1988) and Hart (1973). The total length of all fishes was recorded to the nearest 5 mm. Whole fish were weighed whenever possible. Gonads were examined to determine sex. Otoliths were removed from rockfishes and halibut, and the fourth-eighth rays of the posterior dorsal fin were removed from lingcod for age determination. Halibut otoliths were cleared in glycerin and water and read under a dissecting microscope. A subsample of 105 otoliths was aged and sent to the IPHC for assessment of between-agency variation. Rockfish otoliths were read using the break-and-burn technique (Chilton and Beamish 1982). Lingcod fin rays were dried and embedded in marine fiberglass resin, then cross-sectioned and read under a dissecting microscope (Beamish and Chilton 1977). Before ageing structures collected in 1991, all readers examined at least 50 structures from previous years to minimize between-year drift.

The spatial distribution of fishing effort was estimated by interviewing a portion of returning anglers. The most knowledgeable angler was interviewed from private boats, and either a skipper or deck hand was interviewed from charter boats to ensure accurate reporting. Technicians recorded the number of anglers, the type of boat trip (private or charter), and the area(s) fished. Interviews were conducted on an opportunistic basis and were not strictly random. However, technicians attempted to gather interviews in proportion to the number of boats that fished each day. Because interviews were conducted in conjunction with fish sampling, technicians tended to interview successful anglers. At Valdez, Whittier, and Seward, effort was recorded by ADF&G statistical areas. At Homer and Deep Creek, effort was recorded by four broad areas: (1) north of the latitude of Anchor Point, (2) east of a line between Anchor Point and Dangerous Cape (Kachemak Bay), (3) south of a line between Point Adam and Cape Douglas, and (4) all other Cook inlet waters. The distribution of effort was expressed as the proportion of boat trips in each area. If a boat fished in more than one area on a given day, a boat trip was tallied for each area fished that day.

Data Analysis

The proportional contribution of each rockfish species to the sport harvest (Objective 1) was estimated as (Cochran 1977):

$$\hat{p}_{ij} = \frac{n_{ij}}{n_j}, \tag{1}$$

where:

$\hat{p}_{ij}$ = the estimated proportion of species i in the harvest in month j,

n_{ij} = the number of rockfish of species i sampled in month j, and

n_j = the number of rockfish of all species sampled in month j.

The unbiased estimator of the variance of each proportion was:

$$\hat{Var}(p_{ij}) = \frac{\hat{p}_{ij}\,(1 - \hat{p}_{ij})}{n_j - 1}. \tag{2}$$

The finite population correction (FPC) to the estimated variance (Cochran 1977) was ignored because sample size was small relative to the harvest in most cases. Estimates of variance were therefore conservative (only slightly larger than if harvest were known).

Rockfish species composition was compared between sites and between months using chi-square contingency tables. Monthly data were pooled to obtain species composition for the entire season at each site using equations 1 and 2, assuming the number of rockfish sampled each month was proportional to the harvest.

The proportions of rockfish, lingcod, and halibut in each age, sex, and size class were estimated using equations 1 and 2 by substituting age, size, or sex for species (Objectives 2, 5, and 8). Age, length, and sex composition estimates were desired that were within 0.10 of the true proportions at least 95% of the time. Sample sizes of 128 fish were required to meet this goal (Thompson 1987). Chi-square contingency tables were used to compare age and sex composition between months and locations (Conover 1980). Because the groundfishes sampled generally had a large number of age classes, age group data were pooled for tests. Differences in length distributions were tested using Anderson-Darling k-sample tests (Scholz and Stephens 1987). The test statistic T_{akn} was employed to determine P values of tests.

Since rockfish and lingcod were given highest sampling priority, their sample sizes were assumed to be proportional to harvest. Halibut, on the other hand, were not sampled until rockfish and lingcod sampling goals were met. Therefore, halibut sample sizes were not proportional to harvest. When differences in age or length composition between months were statistically significant, the monthly estimates were weighted to compute age or length composition for the entire season as follows:

$$\hat{p}_i = \sum_{j=1}^{m} \hat{w}_j \frac{n_{ij}}{n_j}, \tag{3}$$

where:

$\hat{p}_i$ = the estimated proportion in age or length group i in the harvest during the season,

n_{ij} = the number of fish of group i sampled in month j,

n_j = the number of fish sampled in month j,

m = the number of months sampled, and

$\hat{w}_j$ = the estimated proportion of the total harvest that occurred during month j.

The $\hat{w}_j$ were estimated using the number of anglers interviewed each month for ancillary fishery information. Although the interviews were not strictly random, technicians attempted to obtain interviews in proportion to effort. If effort was proportional to harvest for halibut, then these interviews were the best available weighting factors. The only other data available to estimate the proportions of halibut harvested each month were records kept by some charter operators in Homer. These data probably underestimated the proportion of the halibut harvest that occurred in July and overestimated the proportions early and late in the season. This would have occurred because harvest by charter boat anglers is limited by the number of boats operated at the peak of the season. Charter operators strive to keep the boats booked early and late in the season also. By contrast, participation by private boat anglers is unrestricted and typically is highest during July and August.

The minimum variance of each p_i was estimated as:

$$\hat{Var}(p_i) = \sum_{j=1}^{m} \hat{w}_j^2 \left[\frac{\hat{p}_{ij}(1 - \hat{p}_{ij})}{n_j - 1} \right]. \tag{4}$$

These were minimum variance estimates because the w_js were estimated with unknown precision and are therefore assumed to have no variance.

Mean lengths at age of all species were estimated as the arithmetic means (Objectives 3, 6, and 9). The standard errors of mean lengths were computed ignoring the FPC, and confidence intervals were estimated assuming lengths were normally distributed at each age.

Rockfish mortality rates (Objective 4) were estimated using age composition data from 1991 only. The instantaneous mortality rate (Z) was estimated as the slope of the regression of log n_i on i, where n_i = the number of age i fish sampled. Only fully recruited ages were used in the regression (Ricker 1975; pages 33-35). The terminus of the catch curve was chosen as the last age represented by less than 1% of the total sample size for at least 5 consecutive years.

The unbiased estimation of Z using catch curve analysis required that: (1) the sample was representative of the age groups in question, (2) recruitment and mortality were constant over time, and (3) the mortality rate was uniform for all ages included in the regression. The instantaneous natural mortality rate M would have been equal to the total mortality rate Z if either fishing mortality was negligible or the fleet was "fishing up" at a rapid pace, i.e. the harvest came from essentially unexploited portions of the population. If the fleet was not "fishing up" but the exploitation rate was constant for all recruited ages, then Z represented a maximum estimate of M.

The annual survival rate of lingcod supporting the Seward area fishery (Objective 7) was estimated using age composition (Vincent-Lang 1991) and effort data from the period 1987-1991. Only effort and harvest data provided by dispatch officers at the U.S. Air Force and U. S. Army recreation camps in Seward were used. These data were assumed to be complete counts except for an insignificant amount of harvest and effort by U.S. Air Force boats during the period August 24-September 10, 1989 (Carlon and Vincent-Lang 1990). Data from military camps were preferable to private and charter boat data because military boats primarily target groundfish. In addition, the proportion of effort targeted on groundfish by private and charter boats was unknown for the same period.

Annual survival rates (S) were estimated for each of the 1976-1981 cohorts over the years 1987-1991 using the relationship of abundance from one year to the next:

$$S = N_{t+1} / N_t \tag{5}$$

where N_t is abundance of a cohort in year t. Because abundance data were not available, survival was estimated by substituting harvest rates for abundance:

$$S = (H/f)_{t+1} / (H/f)_t, \tag{6}$$

where H = the number of lingcod in the cohort harvested and f = angler effort in the same year. The harvest of each cohort H was estimated as the product of the total harvest (all ages) and the proportional contribution of that cohort. The valid substitution of H/f for N relied on a proportional relationship between C/f and abundance (N) from the Baranov catch equation (Ricker 1975, p. 13):

$$C/f = qN, \tag{7}$$

where C = the number of fish caught and q = the proportion of the population caught by one unit of fishing effort. Unbiased estimation of survival rate by this method assumed that q was constant across years and that effort, harvest, and age composition were estimated accurately.

RESULTS

Data were collected at Valdez in 1990 from June 17 through September 16. Sampling in 1991 was conducted from late May through mid-September. Startup dates varied by port because of hiring and logistical constraints. Dates sampled at each port were:

Deep Creek	May 26 - September 1
Homer	May 24 - September 8
Seward	June 18 - September 14
Whittier	June 24 - September 8
Valdez	June 7 - September 4.

Data were collected from 3,134 rockfish, 820 lingcod, and 3,317 halibut in 1991 (Table 2), and from 219 rockfish and 841 halibut in 1990. The largest number of rockfish and lingcod were sampled at Seward, the primary port of landings for these species. The largest number of halibut were sampled at Valdez. High daily variation in catch of all species was largely due to variation in weather and boating conditions.

Rockfishes

Species Composition:

Twenty species of rockfish were recorded in the 1991 sport harvest (Table 3, Appendix B1). Black rockfish or yelloweye rockfish were most abundant in landings at all ports, although black rockfish were uncommon at Whittier (Figure 5). Quillback rockfish constituted a greater proportion of the harvest at Valdez and Whittier than at other sites. Copper rockfish were sampled almost exclusively at Valdez. Species composition was significantly different between ports in June, July, August, and for the entire 1991 season (Table 4). Species composition was also different between months at all sites in 1991 and at Valdez in 1990 (Table 5). At Valdez, significant differences were noted in species composition between 1990 and 1991 ($\chi^2 = 47.028$, $P < 0.001$, df = 4) with black rockfish more common in the 1991 harvest.

Age, Length, and Sex Composition:

A total of 2,923 otoliths were aged from 20 species of harvested rockfish (Table 6). Rockfishes ranged from 6 to 92 years old. Sample sizes were not adequate in 1991 to estimate age, length, and sex composition of all rockfishes with the desired levels of precision and accuracy every month at every port. Therefore, estimates were computed for black rockfish and yelloweye rockfish at most ports in most months, and for quillback rockfish sampled at Valdez in 1991.

Black rockfish harvested at Homer, Seward, and Valdez ranged from 8 to 37 years old, but most were 10-20 years old (Figure 6). Recruitment to the sport fishery was rather abrupt and occurred at ages 8-14. Age composition was significantly different between ports ($\chi^2 = 57.457$, $P < 0.001$, df = 6). The modal ages ranged from 13 to 15. The descending right limb of the Homer age distribution formed a smooth arc suggesting that mortality has been relatively constant over all ages. By contrast, the right limbs of the Seward

Table 2. Number of groundfish sampled by month and location at Southcentral Alaska ports in 1991.

Location	Month	Halibut	Rockfishes	Lingcod
Deep Creek	May	28	0	0
	June	125	0	0
	July	156	0	0
	August	155	0	0
	September	11	0	0
		475	0	0
Homer	May	83	0	0
	June	145	87	21
	July	169	199	39
	August	231	123	13
	September	104	3	0
		732	412	73
Seward	June	18	184	98
	July	157	545	211
	August	288	743	285
	September	44	183	37
		507	1,655	631
Whittier	June	0	8	0
	July	43	131	1
	August	11	50	3
	September	0	15	0
		54	204	4
Valdez	June	439	198	8
	July	639	329	14
	August	428	308	77
	September	43	28	13
		1,549	863	112
Totals, All Sites:		3,317	3,134	820

Table 3. Rockfishes identified from the sport harvest landed at Valdez, Whittier, Seward, and Homer in 1991.

Common Name[a]	Scientific Name
Black rockfish	*Sebastes melanops*
Bocaccio	*S. paucispinus*
Brown rockfish	*S. auriculatus*
Canary rockfish	*S. pinniger*
China rockfish	*S. nebulosus*
Copper rockfish	*S. caurinus*
Dusky rockfish	*S. ciliatus*
Harlequin rockfish	*S. variegatus*
Pacific Ocean perch	*S. alutus*
Quillback rockfish	*S. maliger*
Redstripe rockfish	*S. proriger*
Rosethorn rockfish	*S. helvomaculatus*
Rougheye rockfish	*S. aleutianus*
Sharpchin rockfish	*S. zacentrus*
Shortraker rockfish	*S. borealis*
Silvergray rockfish	*S. brevispinus*
Splitnose rockfish	*S. diploproa*
Tiger rockfish	*S. nigrocinctus*
Yelloweye rockfish	*S. ruberrimus*
Yellowtail rockfish	*S. flavidus*

[a] Source: Robins et al. 1980.

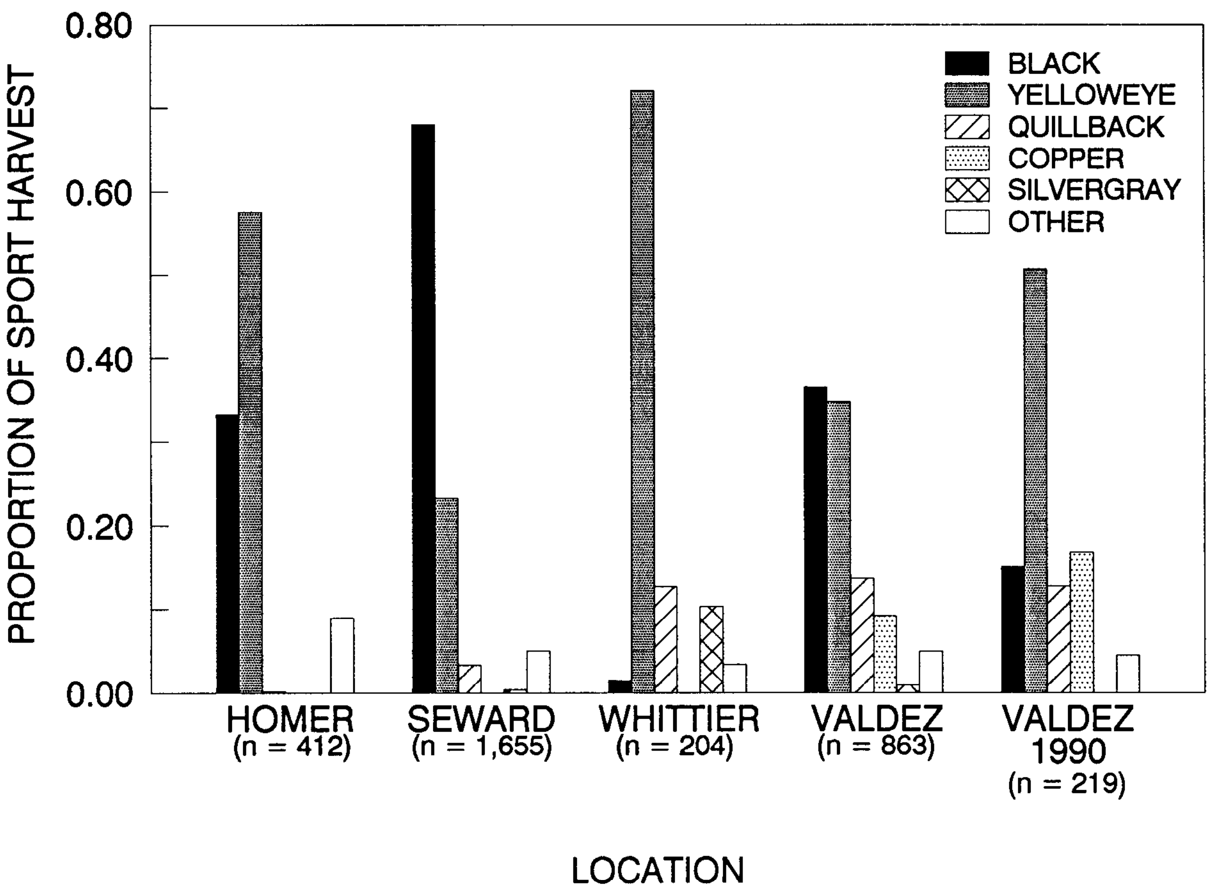

Figure 5. Species composition of rockfishes harvested by sport anglers at Homer, Seward, and Whittier in 1991, and at Valdez in 1990 and 1991.

Table 4. Results of chi-square tests for differences in rockfish species composition between ports in June, July, August, and during the entire 1991 season (June-September). Insufficient numbers of fish were collected to conduct a test for September. The null hypothesis that species proportions were the same between ports was rejected for all tests at 95% confidence (P values were less than 0.050).

Period	Species Included in Test	Ports Included in Test	χ^2	df	P value
June	Black Yelloweye Other	Homer Seward Valdez	116.06	4	< 0.001
July	Black Yelloweye Quillback Other	Homer Seward Valdez Whittier	297.89	9	< 0.001
August	Black Yelloweye Other	Homer Seward Valdez Whittier	184.64	6	< 0.001
June-September	Black Yelloweye Quillback Other	Homer Seward Valdez Whittier	662.69	9	< 0.001

Table 5. Results of chi-square tests for differences in rockfish species composition between months at Valdez, Whittier, Seward, and Homer, 1990 and 1991. The null hypothesis that species proportions were the same between months was rejected for all tests at 95% confidence (P values were less than 0.050).

Location and Year	Species Categories in Test	Months Included in Test	χ^2	df	P value
Homer 1991	Black Yelloweye Other	Jun - Aug	77.79	4	< 0.001
Seward 1991	Black Yelloweye Quillback Other	Jun - Sep	35.31	9	< 0.001
Whittier 1991	Yelloweye Quillback Silvergray Other	Jul - Aug	11.01	3	0.012
Valdez 1990	Black Yelloweye Copper Quillback Other	Jun - Aug	27.92	8	< 0.001
Valdez 1991	Black Yelloweye Copper Quillback Other	Jun - Sep	110.25	12	< 0.001

Table 6. Range of ages and lengths of rockfishes harvested by sport anglers at Valdez, Whittier, Seward, and Homer in 1991.

Species	Age (years)		Length (cm)	
	Range	n[a]	Range	n[a]
Black rockfish	8-37	1,468	35.0-69.0	1,550
Bocaccio	12-44	21	32.9-58.5	20
Brown rockfish	21	1	49.0	1
Canary rockfish	12-20	9	33.0-53.5	7
China rockfish	15-48	21	29.0-40.0	18
Copper rockfish	9-45	20	20.4-55.0	80
Dusky rockfish	6-49	74	32.5-54.2	74
Harlequin rockfish	13-21	3	30.9-33.4	3
Pacific Ocean perch	12-31	2	41.5-46.8	2
Quillback rockfish	12-62	197	21.0-53.0	195
Redstripe rockfish	13-38	2	29.0-35.1	2
Rosethorn rockfish	20	2	41.0-41.5	2
Rougheye rockfish	18-28	5	39.1-71.0	5
Sharpchin rockfish	24	1	27.3	1
Shortraker rockfish	30	1	56.0	1
Silvergray rockfish	11-35	35	28.5-61.0	36
Splitnose rockfish	9-16	4	21.4-30.0	4
Tiger rockfish	17-63	17	34.0-49.5	17
Yelloweye rockfish	9-92	1,036	25.8-85.5	1,001
Yellowtail rockfish	13-40	4	41.5-50.5	4
Totals		2,923		3,024

[a] Number of fish aged or measured.

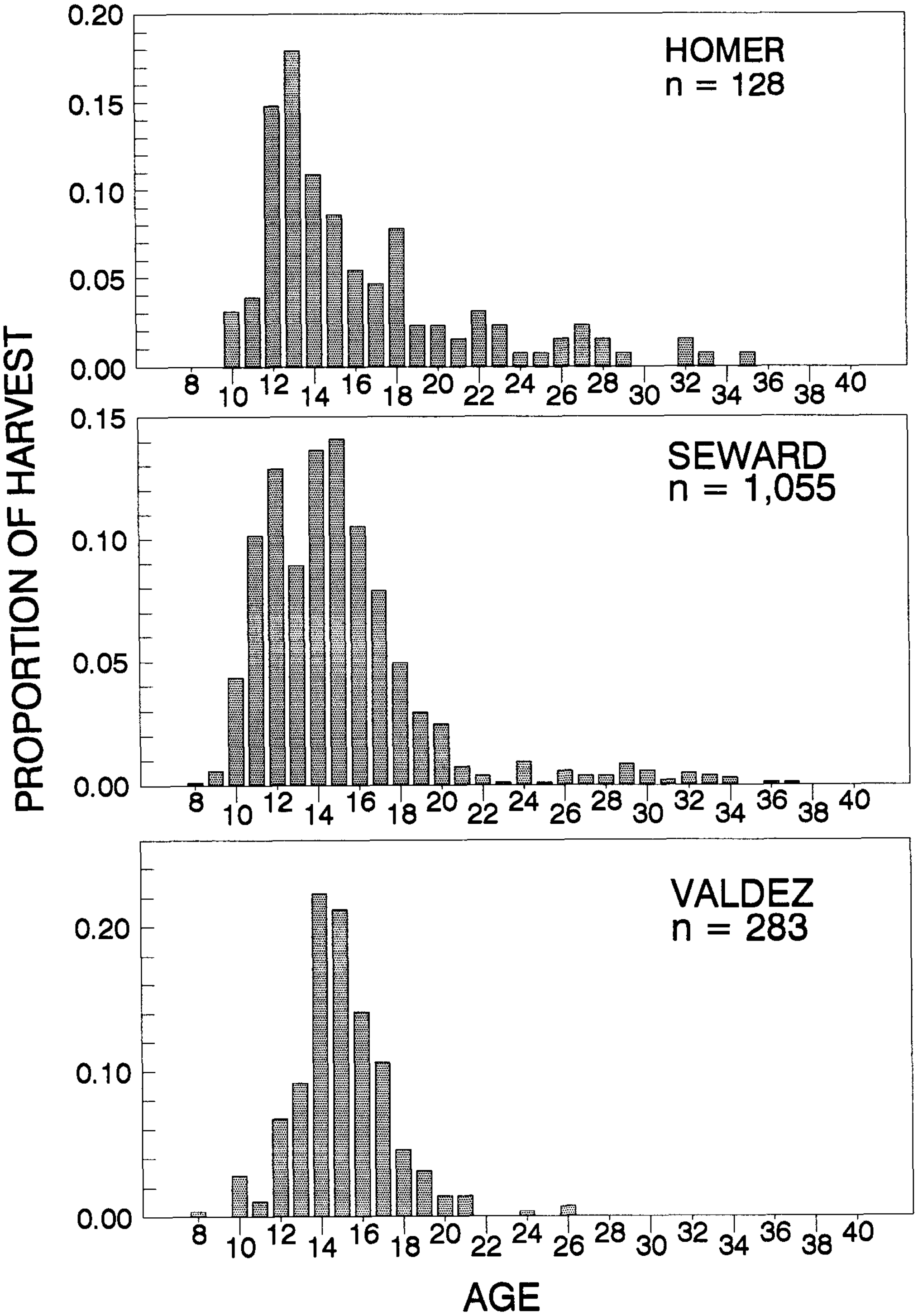

Figure 6. Estimated age composition of black rockfish harvested by sport anglers at Homer, Seward, and Valdez, 1991.

and Valdez age distributions declined sharply to age 21, suggesting much lower mortality after this age.

Black rockfish age composition differed between months at Valdez ($\chi^2 = 15.595$, $P = 0.016$, $df = 6$). Although the modal ages remained at 14-15 during June through August, the relative harvest of 8- to 13-year-old fish was higher in August. No differences in age composition were detected between the months of June, July, and August at Seward ($\chi^2 = 6.437$, $P = 0.696$, $df = 9$) or Homer ($\chi^2 = 12.046$, $P = 0.061$, $df = 6$).

Black rockfish sampled ranged from 35 cm to 69 cm long (Table 6). Length composition was significantly different between ports ($T_{akn} = 52.754$, $P < 0.010$, $m = 2$) with the largest fish landed at Valdez (Figure 7). Monthly estimates of length composition were significantly different at Valdez ($T_{akn} = 12.221$, $P < 0.010$, $m = 2$) and Homer ($T_{akn} = 3.885$, $P < 0.010$, $m = 2$), but not at Seward ($T_{akn} = 0.262$, $P > 0.750$, $m = 3$). Monthly differences in length composition mirrored the observed differences in age composition. Low sample sizes at other ports prevented monthly comparisons.

Sex composition of black rockfish varied between ports (Table 7). Fifty-five percent of the harvest at Homer was females, with no difference between July and August, the major months of harvest ($\chi^2 = 1.899$, $P = 0.168$, $df = 1$). Females represented 60% of the Seward harvest, and although the proportion of females varied from 49% to 63% between June and September, the differences were not significant ($\chi^2 = 6.919$, $P = 0.075$, $df = 3$). The proportion of females in the Valdez harvest increased significantly from 69% in June to 95% in August ($\chi^2 = 17.087$, $P < 0.001$, $df = 2$). Tests for differences in sex ratio between ports included only July and August data to avoid small samples. Differences between ports were highly significant ($\chi^2 = 66.395$, $P < 0.001$, $df = 2$).

Harvested yelloweye rockfish ranged from 9 to 92 years old. Recruitment was more gradual than for black rockfish, generally occurring between the ages of 10 and 25 (Figure 8). Two distinct modes were present in harvests at Whittier and Valdez: one at about ages 14-16, and another at ages 23-24. The Seward and Homer harvests had modal ages of 24 and 26. Differences in age composition between all sites were significant ($\chi^2 = 119.8$, $P < 0.001$, $df = 9$), but no difference was found between Seward and Homer ($\chi^2 = 6.401$, $P = 0.094$, $df = 3$). No difference was detected either between the 1990 and 1991 harvests at Valdez ($\chi^2 = 3.651$, $P = 0.302$, $df = 3$).

Yelloweye rockfish age composition differed between June, July, and August at Seward ($\chi^2 = 22.948$, $P = 0.003$, $df = 8$) and Valdez ($\chi^2 = 22.382$, $P < 0.001$, $df = 6$). In both cases, rejection of the null hypothesis of similarity was caused by relatively high harvest of younger age groups in June. In fact, no differences were detected between July and August (major harvest period) at Seward ($\chi^2 = 5.646$, $P = 0.227$, $df = 4$) or Valdez ($\chi^2 = 3.184$, $P = 0.364$, $df = 3$). No differences were found in age composition between June, July, and August at Homer ($\chi^2 = 9.728$, $P = 0.137$, $df = 6$), or between July and August at Whittier ($\chi^2 = 4.473$, $P = 0.215$, $df = 3$).

Sampled yelloweye rockfish ranged from 25 cm to 77 cm in length. Differences in length composition between ports were significant ($T_{akn} = 115.104$, $P < 0.010$, $m = 3$). Most fish harvested at Homer and Seward were 40 cm-70 cm

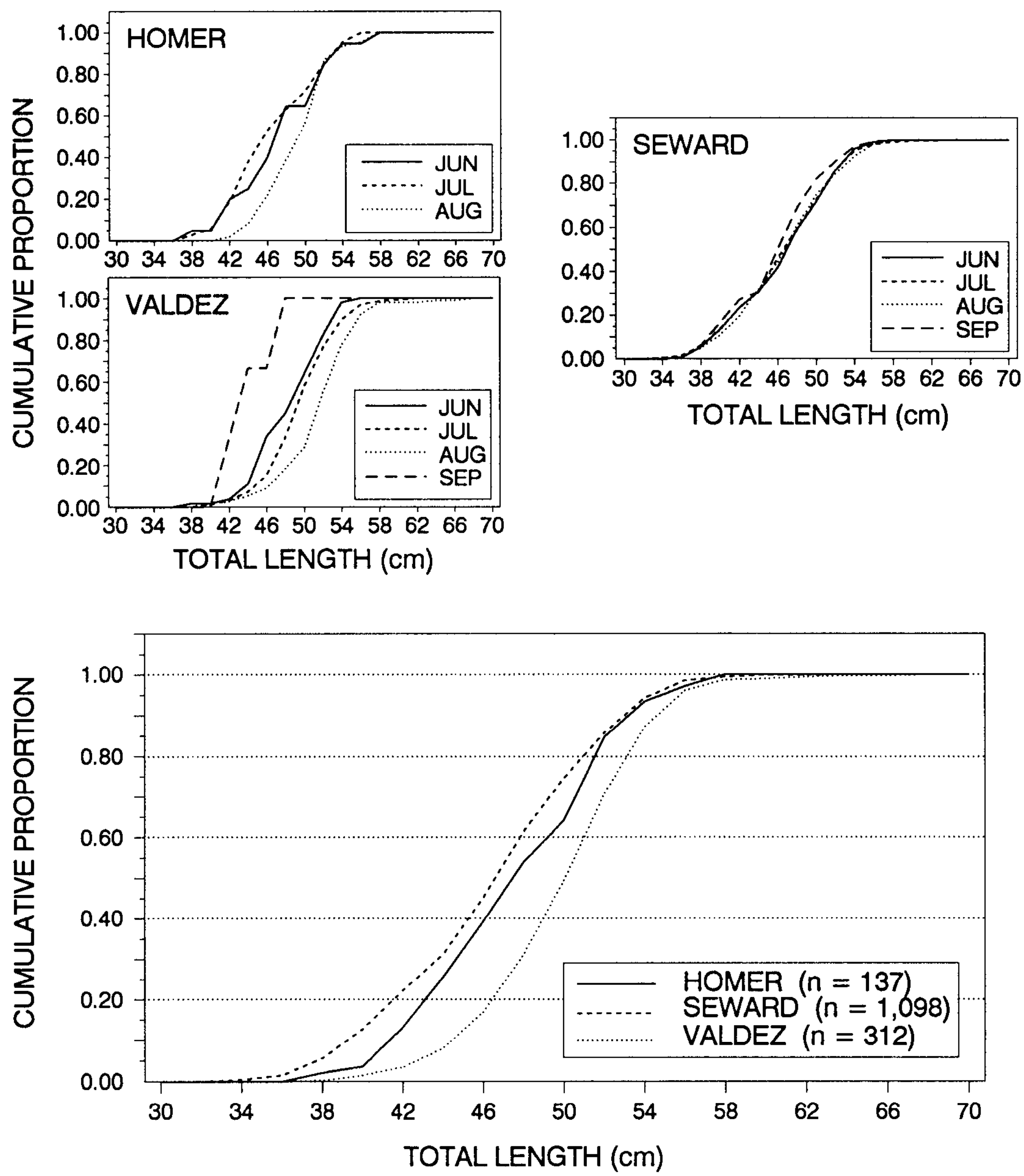

Figure 7. Estimated length composition (cumulative frequency distributions) of black rockfish harvested by sport anglers at Homer, Seward, and Valdez, 1991.

Table 7. Estimated sex composition (proportion female) of black rockfish harvested at Homer, Seward, and Valdez in 1991. Only fish of known sex were included in computation of estimated proportions.

Site	Month	Number Sexed	Number Female	Proportion Female (p)	SE(p)
Homer	Jul	57	22	0.39	0.065
	Aug	46	24	0.52	0.074
	Total	103	46	0.45	0.049
Seward	Jun	92	45	0.49	0.052
	Jul	310	196	0.63	0.027
	Aug	427	255	0.60	0.024
	Sep	136	87	0.64	0.041
	Total	965	583	0.60	0.016
Valdez	Jun	51	35	0.69	0.066
	Jul	125	100	0.80	0.036
	Aug	93	88	0.95	0.024
	Total	269	223	0.83	0.023

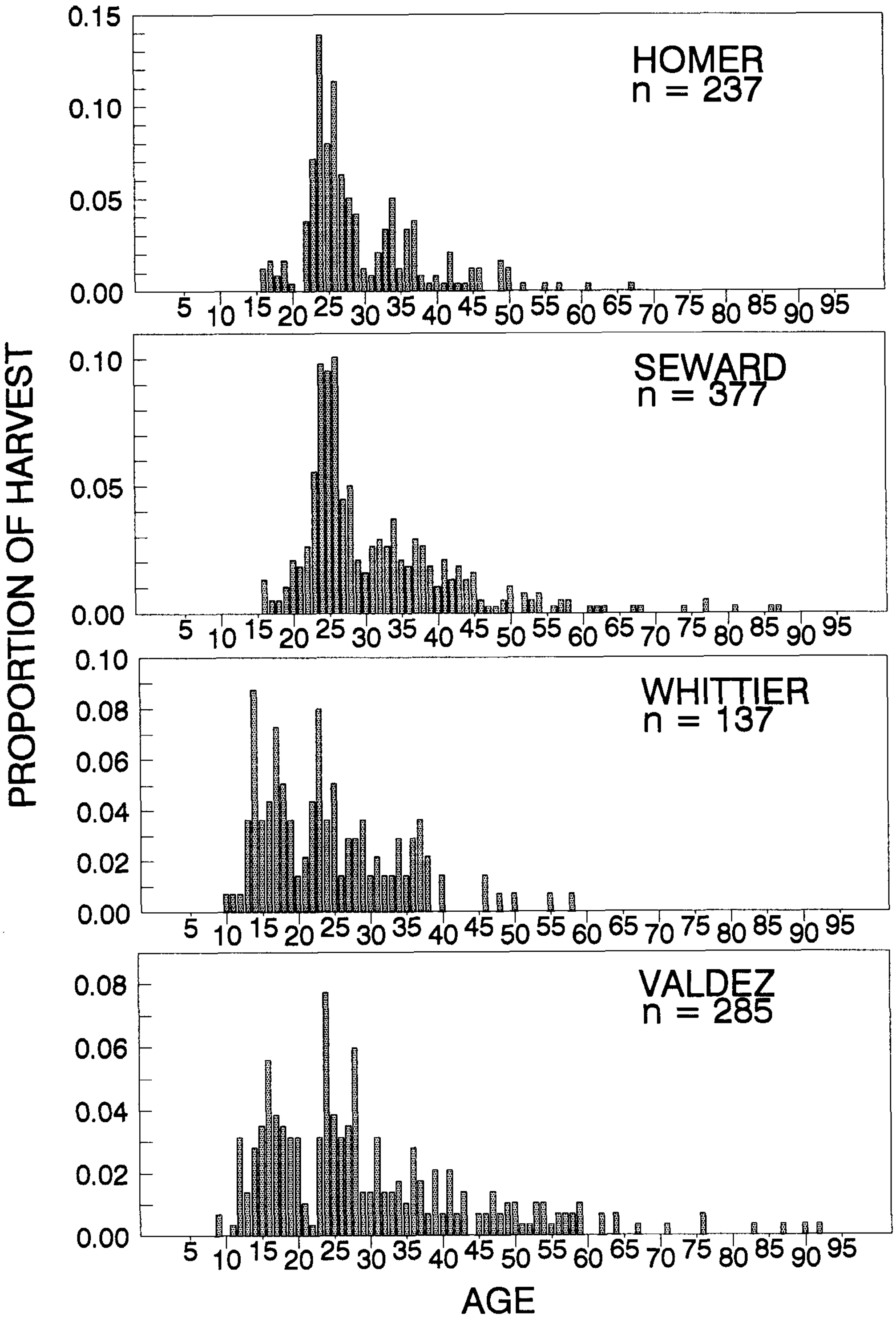

Figure 8. Estimated age composition of yelloweye rockfish harvested by sport anglers at Homer, Seward, and Whittier in 1991, and at Valdez in 1990 and 1991.

long, compared with 30 cm-60 cm at Whittier and Valdez (Figure 9). These differences corresponded to differences in age composition noted above. Although age composition at Valdez was not different between 1990 and 1991, length distributions were markedly different (T_{akn} = 19.298, P < 0.010, m = 1). This inconsistency may have been caused by small sample sizes in 1990 and subsequent low power of tests. Length composition differed by month at Homer (T_{akn} = 5.878, P < 0.001, m = 2), Seward (T_{akn} = 2.894, P = 0.017, m = 3), and Valdez (T_{akn} = 4.117, P = 0.004, m = 3) in 1991, and at Valdez in 1990 (T_{akn} = 6.314, P < 0.010, m = 2). Differences at Seward were less pronounced than at other ports (Figure 9). No differences were detected between July, August, and September at Whittier (T_{akn} = 0.672, P = 0.211, m = 2), but this may have been due to small sample sizes and resultant low power of the test.

The sex ratios of yelloweye rockfish varied between ports but were fairly constant across months at ports with adequate sample sizes (Table 8). Differences in sex ratios between months were not significant at Homer (χ^2 = 0.012, P = 0.912, df = 1), Seward (χ^2 = 2.832, P = 0.418, df = 3), or Valdez (χ^2 = 1.727, P = 0.631, df = 3). The proportion of females in the harvest ranged from 32% at Homer to 60% at Valdez. Differences between ports during July and August, the primary months of harvest, were significant (χ^2 = 21.724, P = 0.001, df = 3).

Quillback rockfish sampled at all ports ranged from 12 to 62 years old. Sample sizes were adequate for estimation of age, length, and sex composition only at Valdez in 1991. The most abundant age group landed was 20-24 years (Figure 10). The right descending limb of the age distribution was very gradual, with a conspicuous absence of 40- to 44-year-old fish. Fish sampled at Valdez were 21 cm-53 cm long. Fish over 38 cm were more common in August than July, causing a significant difference in length distributions between months (T_{akn} = 4.193, P < 0.010, m = 1). Females made up 63% (SE = 4.82) of the harvest in July and August with no difference in sex ratio between months (χ^2 = 0.708, P = 0.400, df = 1).

Mean Length at Age:

The mean length at age was estimated for black rockfish sampled at Homer, Seward, and Valdez, for yelloweye rockfish sampled at all ports, and for quillback rockfish sampled at Valdez. By the time black rockfish recruit to the fishery, they have attained 80%-90% of their asymptotic length of about 50 cm (Figure 11). There did not appear to be major differences in mean length at age of black rockfish between ports.

Unlike black rockfish, yelloweye rockfish are still growing when they recruit to the fishery (Figure 11). There appeared to be differences in size at age of yelloweye rockfish between locations. Fish from Gulf of Alaska sites (Homer and Seward) grow faster and reach a greater average length than fish from Prince William Sound (Whittier and Valdez).

The mean lengths at age of quillback rockfish were lower than those of black or yelloweye rockfish (Figure 11). Similar to black rockfish, it appears that most fish are nearly full grown by the time they recruit to the sport fishery. The maximum average length is about 45 cm.

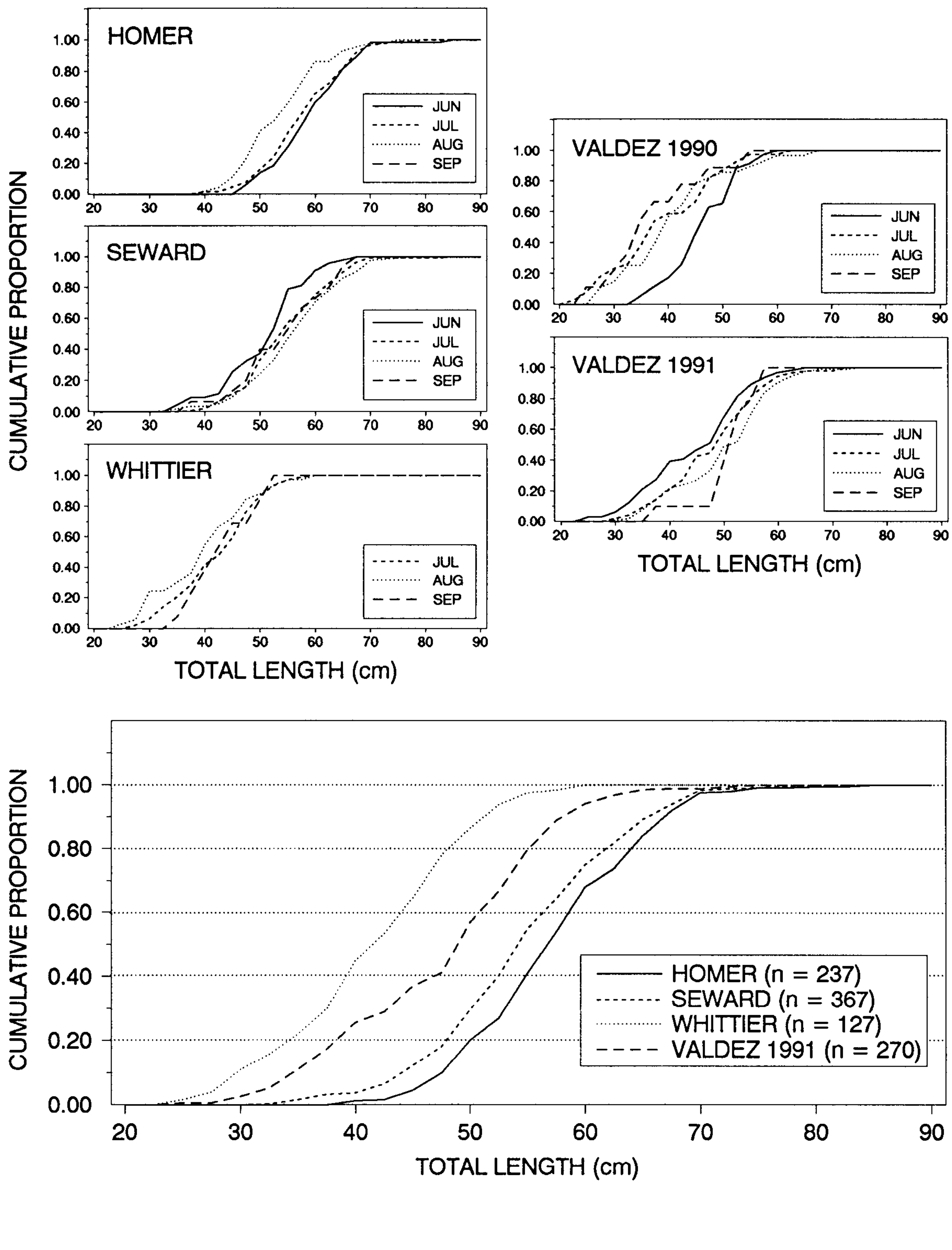

Figure 9. Estimated length composition (cumulative frequency distributions) of yelloweye rockfish harvested by sport anglers at Homer, Seward, and Whittier in 1991, and at Valdez in 1990 and 1991.

Table 8. Estimated sex composition (proportion female) of yelloweye rockfish harvested at Homer, Seward, Whittier, and Valdez in 1991. Only fish of known sex were included in computation of estimated proportions.

Site	Month	Number Sexed	Number Female	Proportion Female (p)	SE(p)
Homer	Jul	113	37	0.33	0.044
	Aug	44	14	0.32	0.071
	Total	157	51	0.32	0.037
Seward	Jun	27	14	0.52	0.098
	Jul	125	51	0.41	0.044
	Aug	161	80	0.50	0.040
	Sep	15	6	0.40	0.131
	Total	328	151	0.46	0.028
Whittier	Total	104	42	0.40	0.048
Valdez	Jun	51	34	0.67	0.067
	Jul	83	46	0.55	0.055
	Aug	95	57	0.60	0.051
	Sep	9	5	0.56	0.176
	Total	269	223	0.60	0.032

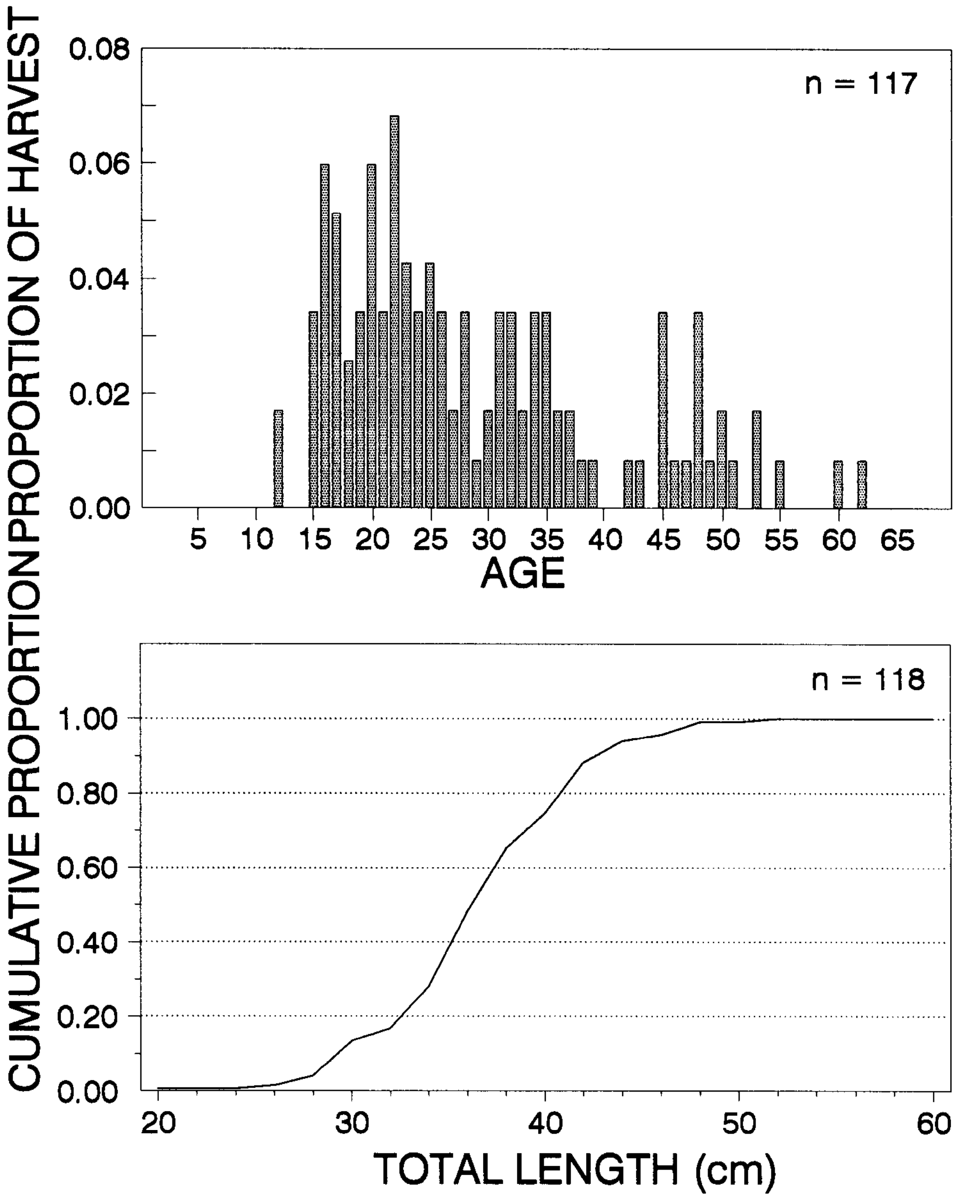

Figure 10. Estimated age and length composition of quillback rockfish harvested by sport anglers at Valdez in 1991.

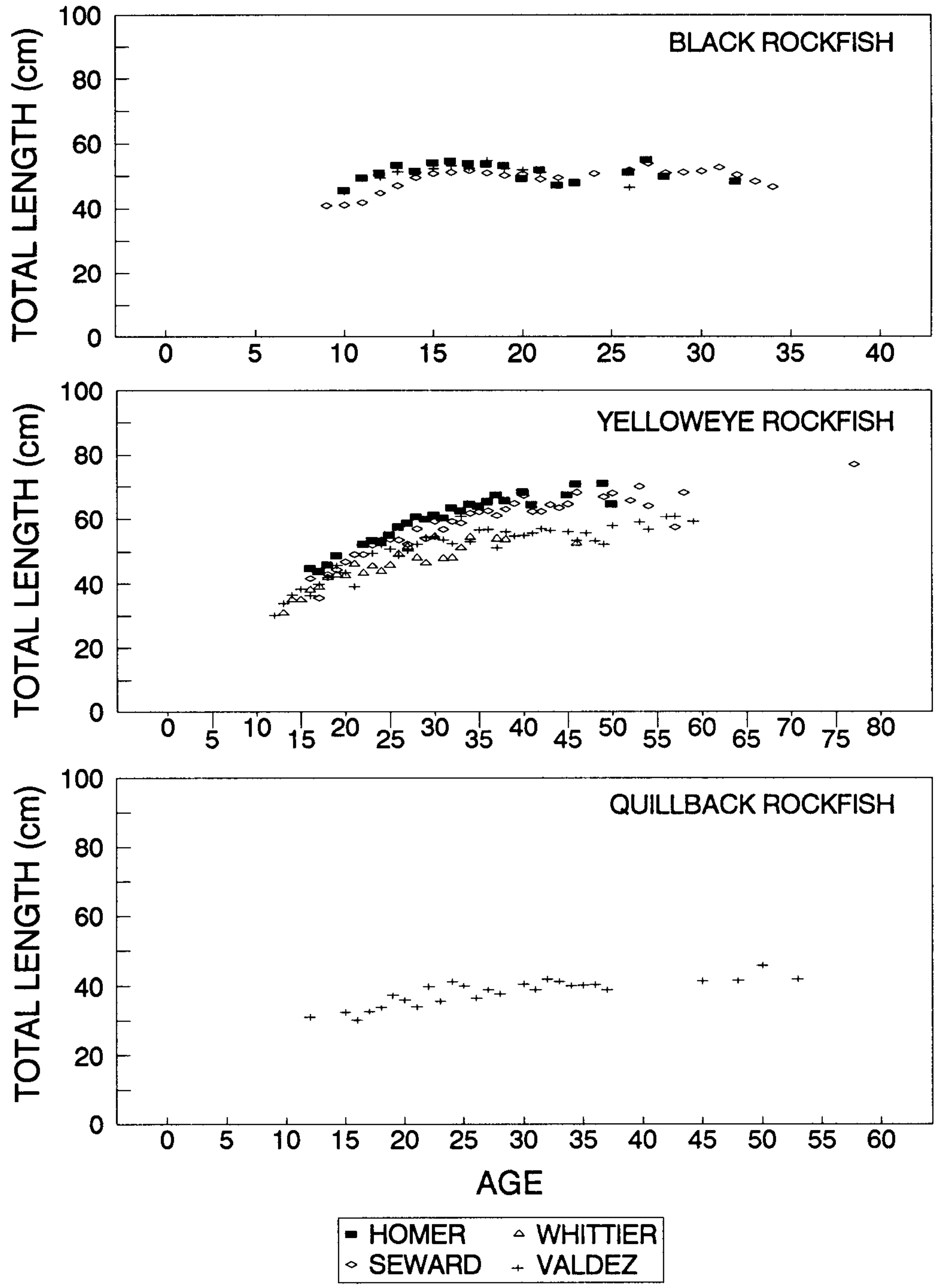

Figure 11. Estimated mean lengths at age of black, yelloweye, and quillback rockfish harvested by sport anglers at Homer, Seward, Whittier, and Valdez in 1991.

Mortality Rates:

Sample sizes were sufficient to estimate total instantaneous mortality rates (Z) for black, yelloweye, and quillback rockfish (Table 9). Estimated instantaneous mortality rates of black rockfish were 0.16 at Homer, 0.50 at Valdez, and 0.51 at Seward. Corresponding annual survival rates ($S = e^{-Z}$) were about 60% at Valdez and Seward and 85% at Homer. Mortality rate estimates for yelloweye rockfish were much lower, ranging from 0.05 at Valdez to 0.09 at Homer. These data suggest that annual survival of yelloweye rockfish is about 91%-95%. The estimated total instantaneous mortality of quillback rockfish at Valdez was 0.05, with a corresponding annual survival rate of 96%. Age-frequency distributions of black, yelloweye, and quillback rockfish were all positively skewed, suggesting that mortality approaches zero for older fish.

Limited information was available to evaluate whether the assumptions of catch curve analysis were met. The slopes of the log-transformed catches were nearly linear for all species and locations, suggesting that either fishing and natural mortality are nearly constant across all recruited ages, or that trends in recruitment were offset by opposite trends in mortality. The bumpy appearance of the age-frequency distributions, particularly for yelloweye rockfish, were probably due to variable recruitment. If the variations were random they would not seriously affect the estimate of Z.

Lingcod

Age, Length, and Sex Composition:

Data were collected from 820 lingcod from all locations except Deep Creek (Table 2). Ages estimated from 797 fish ranged from 4 to 23 years. Lengths of 805 fish ranged from 46.5 cm to 145.0 cm. Although the numbers of fish sampled at Valdez and Homer were small compared to Seward, they probably represented a significant portion of the harvest and are adequate for gross comparisons between sites.

Age composition differed significantly between ports ($\chi^2 = 67.854$, $P < 0.010$, $df = 10$). It was difficult to determine the age of full recruitment because of marked differences in age composition between ports and between years at Seward. The modal age group was 9 at Valdez and 12 at Homer. The dominant age class at Seward was 7 years. Age distributions were more symmetrical at Homer and Valdez than at Seward, where recruitment was almost "knife-edged" (Figure 12). Fish less than 6 years old made up slightly higher proportions of the age compositions at Homer and Valdez than at Seward. No differences in age composition were detected between months at Seward ($\chi^2 = 17.205$, $P = 0.307$, $df = 15$).

Differences in length composition between Homer, Seward, and Valdez were significant ($T_{akn} = 5.341$, $P < 0.010$, $m = 2$). Fish under 70 cm were more abundant in the harvests from Homer and Valdez (Figure 13). No differences were detected in length composition between months at Seward ($T_{akn} = 0.635$, $P = 0.219$, $m = 3$). Females harvested at Seward were larger than males ($T_{akn} = 105.565$, $P < 0.010$, $m = 1$). Comparisons of length distributions between months and sexes were not made for other locations because of small sample sizes.

Table 9. Total instantaneous mortality rate (Z) estimates from black, yelloweye, and quillback rockfish harvested in the sport fisheries at Homer, Seward, and Valdez, 1991. Mortality was estimated using catch curve regression.

Species	Site	Ages Used in Regression	n	r^2 [a]	$\hat{Z}$	$SE(\hat{Z})$
Black Rockfish	Homer	13-28	16	0.721	0.16	0.027
	Seward	15-22	8	0.949	0.51	0.048
	Valdez	15-21	7	0.972	0.50	0.038
Yelloweye rockfish	Homer	24-50	25	0.476	0.09	0.021
	Seward	26-58	31	0.723	0.08	0.009
	Valdez	24-59	35	0.581	0.05	0.008
Quillback rockfish	Valdez	22-51	27	0.371	0.05	0.012

[a] Coefficient of determination of the regression.

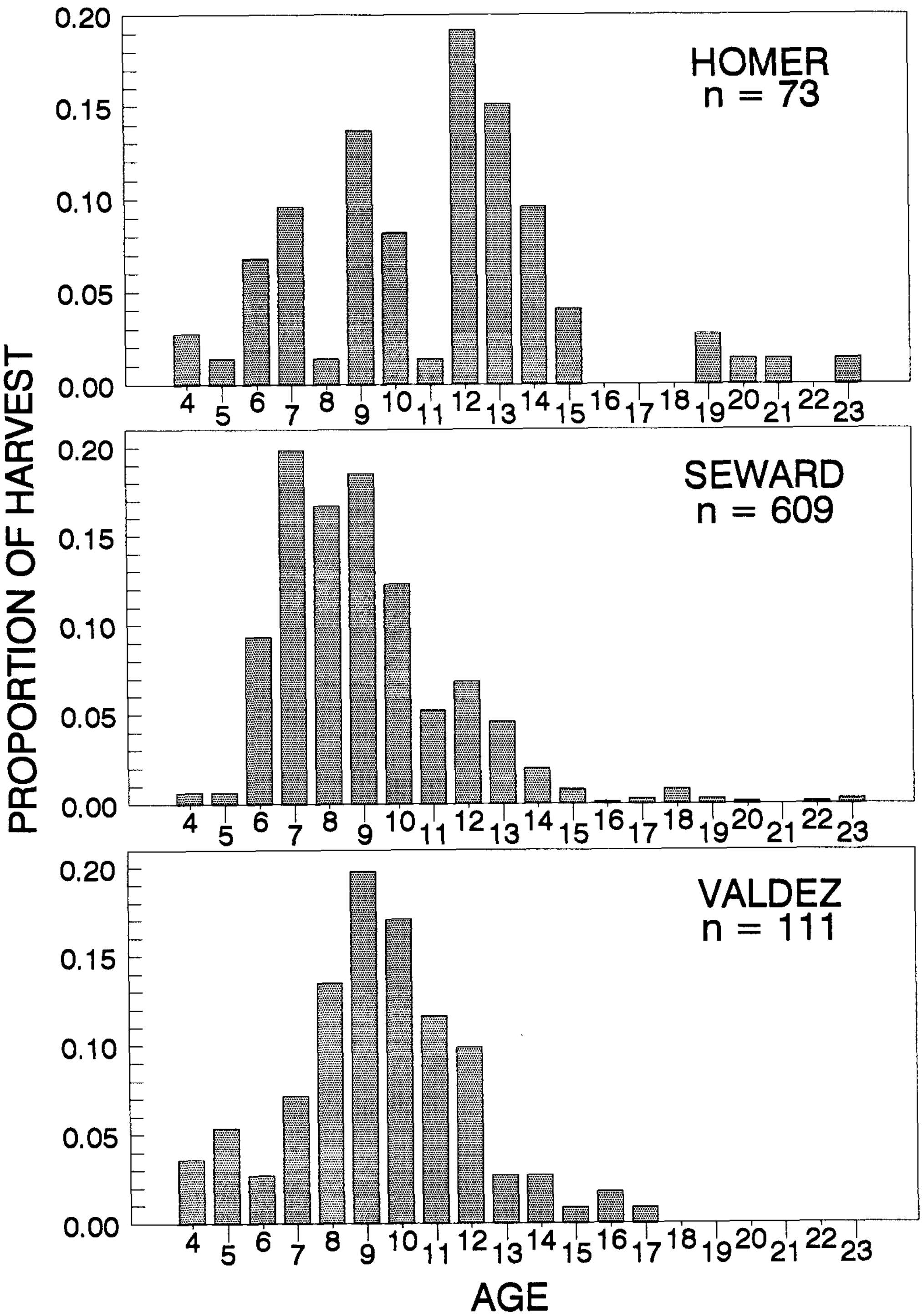

Figure 12. Estimated age composition of lingcod harvested by sport anglers at Homer, Seward, and Valdez in 1991.

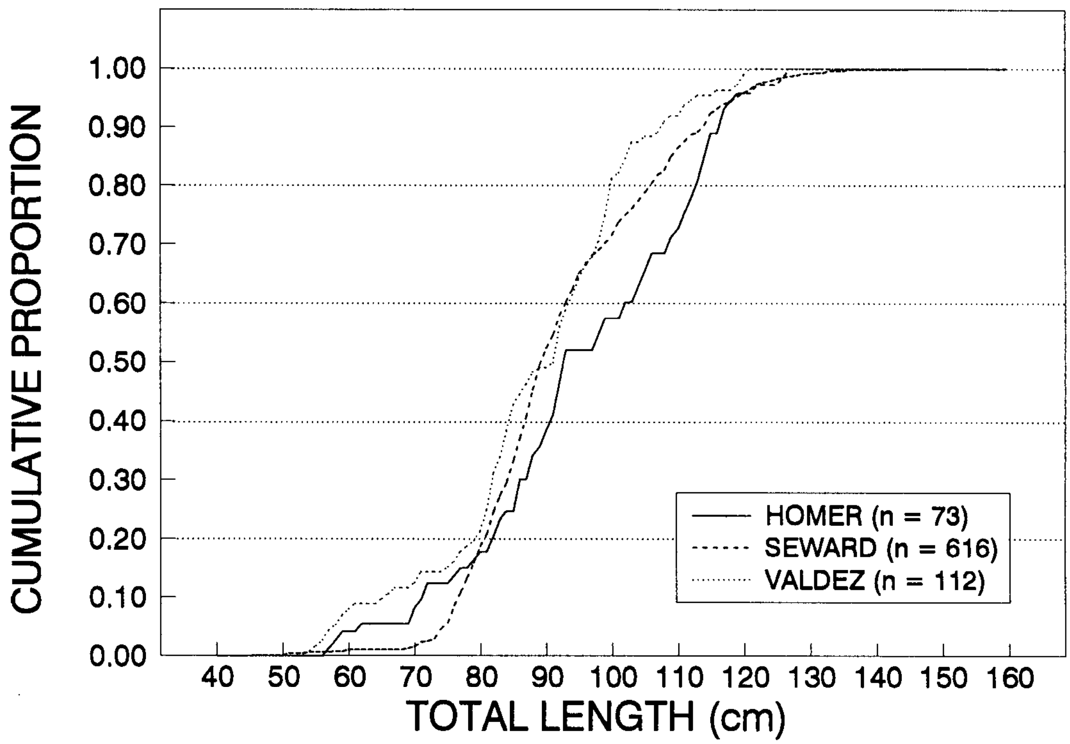

Figure 13. Estimated length composition (cumulative frequency distributions) of lingcod harvested by sport anglers at Homer, Seward, and Valdez in 1991.

Sex composition was dominated slightly by females at all ports. Males made up 47.2% (SE = 2.17, n = 532) of the harvest at Seward, 45.2% (SE = 7.77, n = 42) at Homer, and only 29.1% (SE = 4.35, n = 110) at Valdez. Although the percentage of males in the Seward harvest ranged from 59.2% in June to 28.6% in September, monthly differences were marginally insignificant ($\chi^2 = 7.770$, $P = 0.051$, $df = 3$). Weekly examination of sex composition showed that the proportion of males dropped dramatically by early July, then increased gradually through mid-August (Figure 14). Unfortunately, no sex data were collected prior to June 22.

Mean Length at Age:

Female lingcod grew faster and attained greater lengths at age than male lingcod (Figure 15). Although few young fish were captured, growth prior to age 6 appears to be similar for males and females. Sample sizes were insufficient to estimate mean length at age for all but the major age classes at Homer and Valdez, but growth at those sites appeared to be similar to Seward.

Annual Survival Rate:

Estimation of survival rate was attempted for fully recruited age classes of the 1976-1981 cohorts at Seward. As described in the Data Analysis section, only data from the Seward military recreation camps were used. Many of the survival rate estimates were nonsensical, i.e. annual survival rate exceeded 1.0, particularly during the years 1987-1989. This occurred because catch rates, the chosen indices of abundance, often increased with age for most of the cohorts (Table 10). Increases in catch rates were probably due to incomplete recruitment of some of the ages used, as well as annual changes in catchability (q), thus violating the critical assumption of this analysis. Increases in q could have come about through increased availability of fish to the fishery or through increased ability of the fleet to find and catch remaining concentrations of older lingcod.

Halibut

Age, Length, and Sex Composition:

Data were collected from 841 halibut at Valdez in 1990, and from 3,317 halibut from all sites in 1991 (Table 2). Although Valdez provided nearly half of the samples in 1991, the number of fish harvested was unquestionably greatest at Homer. Sample sizes at Homer were relatively low because the technician also sampled at Deep Creek. Whittier had the fewest samples (54), but these fish probably represented a large percentage of the available landings. Effort directed at groundfish was much lower than expected at Whittier and charter boat operators at Whittier and Valdez generally reported lower than average catch rates in Prince William Sound in 1991.

The 2,229 halibut aged ranged from 3 to 22 years old. Seasonal shifts in age composition were pronounced at Deep Creek and Homer, with older fish caught during July (Figure 16). Differences between months were significant at Deep Creek ($\chi^2 = 71.429$, $P < 0.001$, $df = 12$) and Homer ($\chi^2 = 162.794$, $P < 0.001$, $df = 16$). Age composition did not change appreciably over time at Seward or Whittier (Figure 17). Differences between the major months of harvest were not significant at Seward ($\chi^2 = 11.819$, $P = 0.159$, $df = 8$) or Whittier

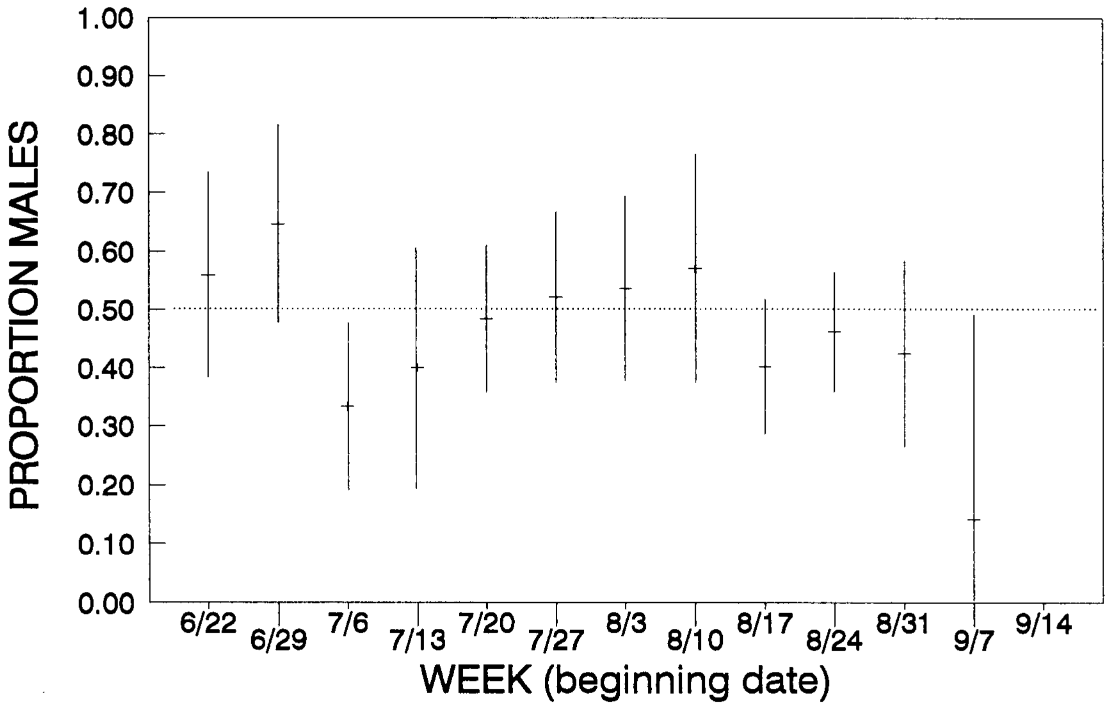

Figure 14. Weekly estimates of the proportion of males in the lingcod harvest by sport anglers at Seward in 1991. Vertical bars represent 95% confidence intervals of the proportions.

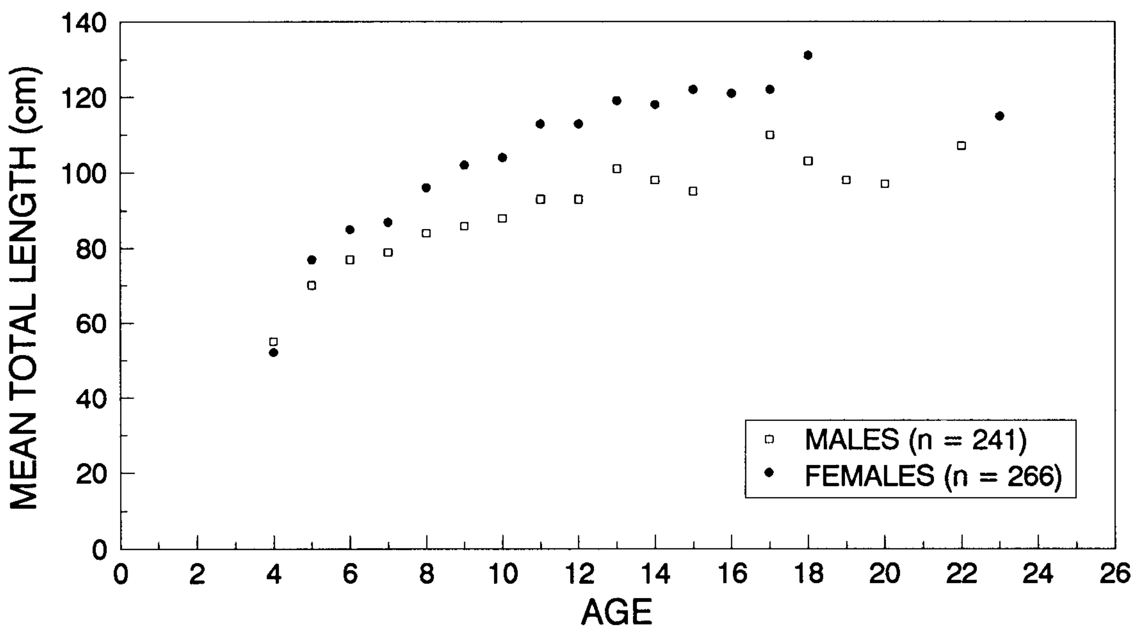

Figure 15. Estimated mean length at age of lingcod harvested by sport anglers at Seward in 1991.

Table 10. Estimated effort (boat trips), harvest (number of fish), and harvest per boat trip (HPUE) of the 1976-1981 lingcod cohorts by Seward military recreation camp anglers during the period 1987-1991.

	Parameter Estimate by Year				
Cohort	1987	1988	1989	1990	1991
EFFORT:					
	778	1,365	688	855	1110
HARVEST:					
1981	111	570	544	710	326
1980	56	285	264	234	139
1979	35	214	145	209	183
1978	70	107	100	276	122
1977	50	285	115	67	52
1976	18	71	15	17	0
HPUE:					
1981	0.143	0.418	0.790	0.830	0.294
1980	0.071	0.209	0.384	0.274	0.125
1979	0.045	0.157	0.210	0.244	0.165
1978	0.090	0.078	0.145	0.322	0.110
1977	0.064	0.209	0.167	0.078	0.047
1976	0.023	0.052	0.022	0.020	

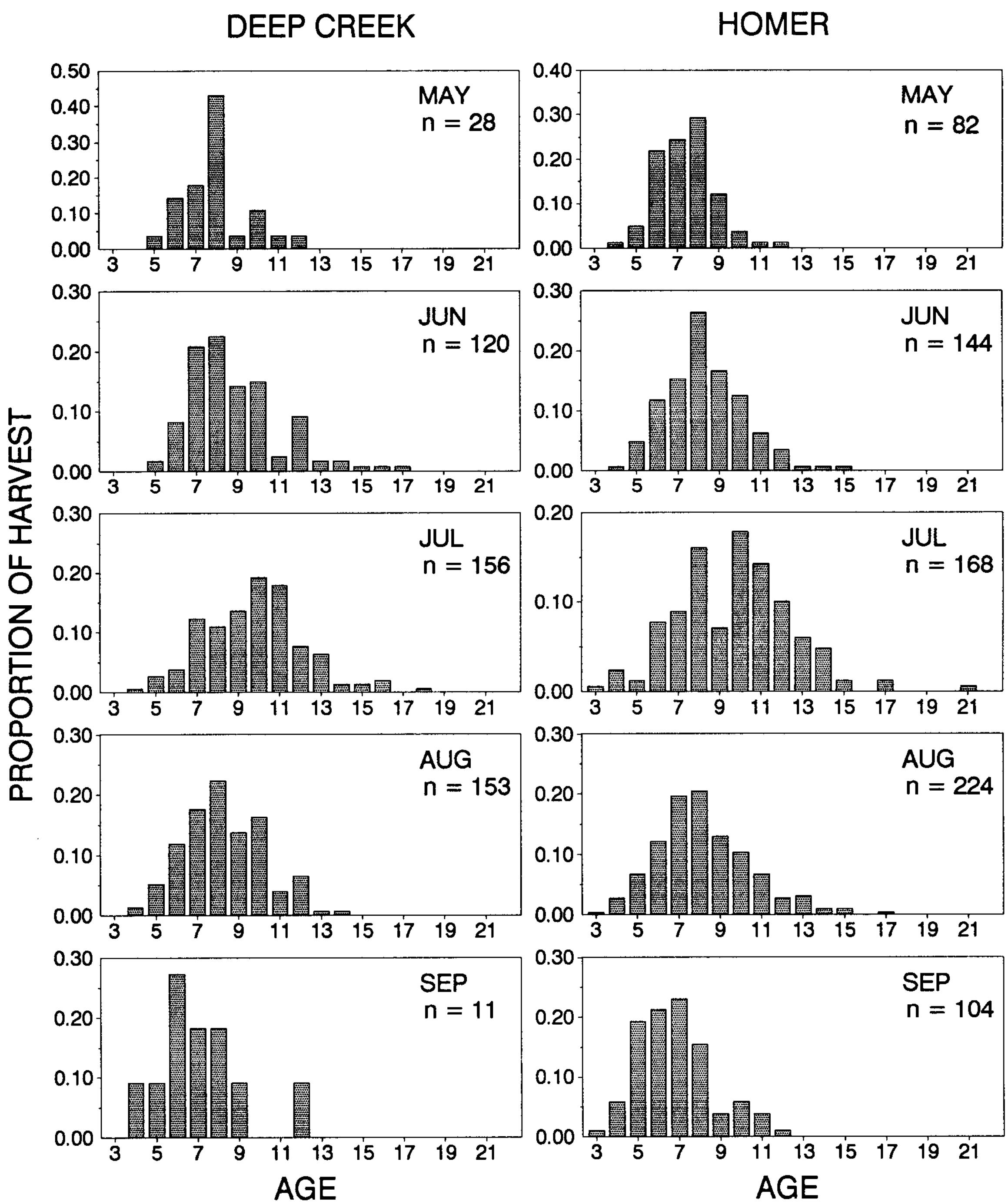

Figure 16. Monthly estimated age composition of halibut harvested by sport anglers at Deep Creek and Homer in 1991.

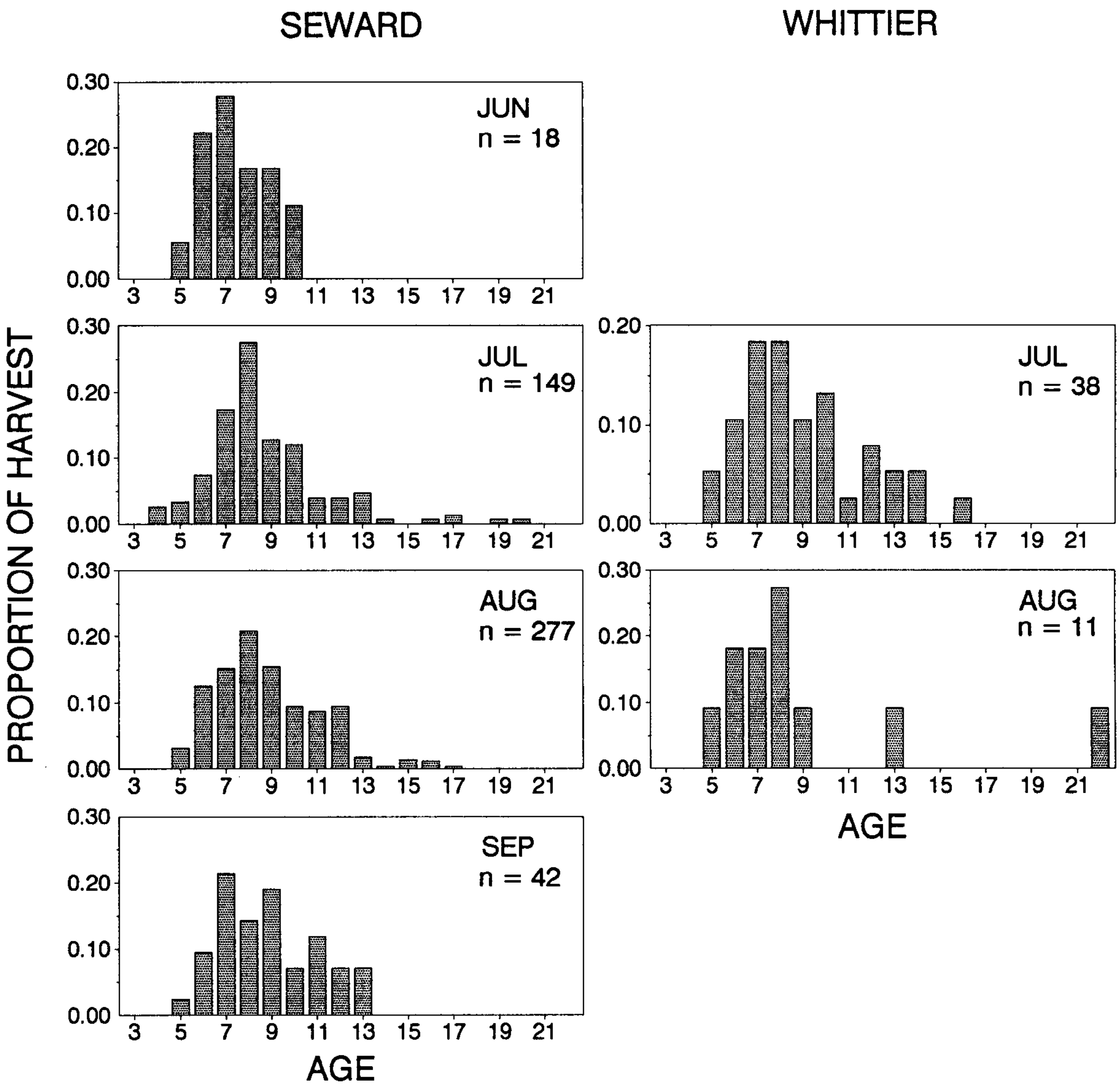

Figure 17. Monthly estimated age composition of halibut harvested by sport anglers at Seward and Whittier in 1991.

(χ^2 = 1.579, P = 0.454, df = 2). At Valdez, differences in age composition between June, July, August, and September were significant (χ^2 = 38.918, P < 0.001, df = 12), but June was the source of most of the χ^2 value. Differences between July-September were not significant (χ^2 = 7.136, P = 0.522, df = 8). In 1990, relatively fewer large halibut were harvested in July than in other months (Figure 18). Differences in age composition between months in 1990 at Valdez were significant (χ^2 = 55.159, P < 0.001, df = 12).

Overall age composition differed significantly between all sites (χ^2 = 38.038, P = 0.009, df = 20). Although age composition was statistically different between sites, there were common features (Figure 19). Halibut begin recruiting to the sport fishery at about age 3 and appear to be fully recruited by age 8 at all sites. The 1982 year class (age 9) appeared slightly weak in most samples. Age 10 fish were unusually abundant in the Deep Creek harvest. Overall, ages 6-12 supported the bulk of the harvest during most months. Age composition for all of Southcentral Alaska will be estimated next year after harvest estimates become available through the statewide postal survey.

At Seward and Whittier, overall estimates of age composition were obtained from pooled monthly data. Because there were monthly changes in age composition at Deep Creek, Homer, and Valdez, age composition for the entire year was estimated for these sites by weighting monthly data by the estimated proportion of harvest that occurred each month. As pointed out in the methods, the best available estimates of these proportions were the numbers of boats interviewed for ancillary information (Table 11).

Although these interview data are the best available weighting factors, they were incomplete and may therefore slightly reduce the accuracy of estimates. Specifically, no interviews were obtained at Deep Creek until June 22 and at Homer until June 14. As approximations, the proportions of interviews obtained in June were subjectively combined to produce weighting factors for the entire period May-June. This was not felt to seriously compromise the data--trials with extreme values of weighting factors produced very little differences in age composition. For example, increasing the proportion of fish caught at Homer in July by ten percent caused shifts in age composition of no more than one percent per age class.

Lengths of 3,273 halibut measured ranged from 27 cm to 221 cm. Seasonal differences in length composition were notable at Homer, Deep Creek, and Valdez. More large halibut were harvested in July and August, while smaller halibut made up the bulk of the harvest in May, June, and September (Figure 20). The trend was most pronounced at Homer. Tests for differences in length composition between months were significant for Deep Creek (T_{akn} = 1.872, P < 0.05, m = 2), Homer (T_{akn} = 27.338, P < 0.010, m = 4), and Valdez (T_{akn} = 21.915, P < 0.010, m = 2). No significant differences between months were noted at Seward (T_{akn} = 0.582, P > 0.100, m = 1). Sample sizes at Whittier were too small for comparisons. Comparison of 1990 and 1991 length composition at Valdez suggests that observed seasonal trends were not necessarily stable from year to year--in 1990, fish over 110 cm made up a greater proportion of the harvest in June, August, and September (Figure 20).

To estimate length composition for the entire year (Figure 20), monthly data from Deep Creek, Homer, and Valdez were weighted as for age composition. Estimates of length composition for these sites were therefore subject to the

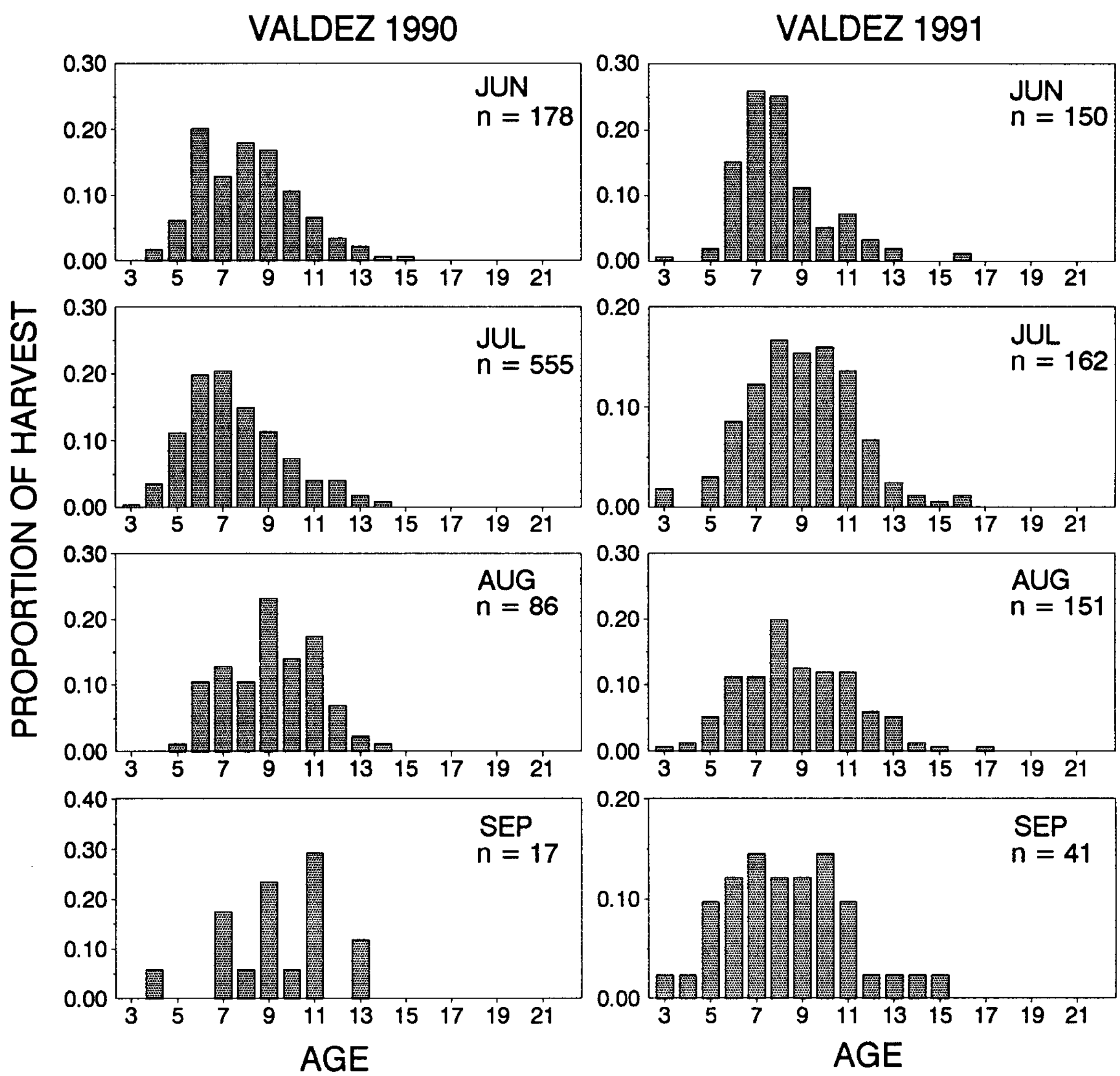

Figure 18. Monthly estimated age composition of halibut harvested by sport anglers at Valdez in 1990 and 1991.

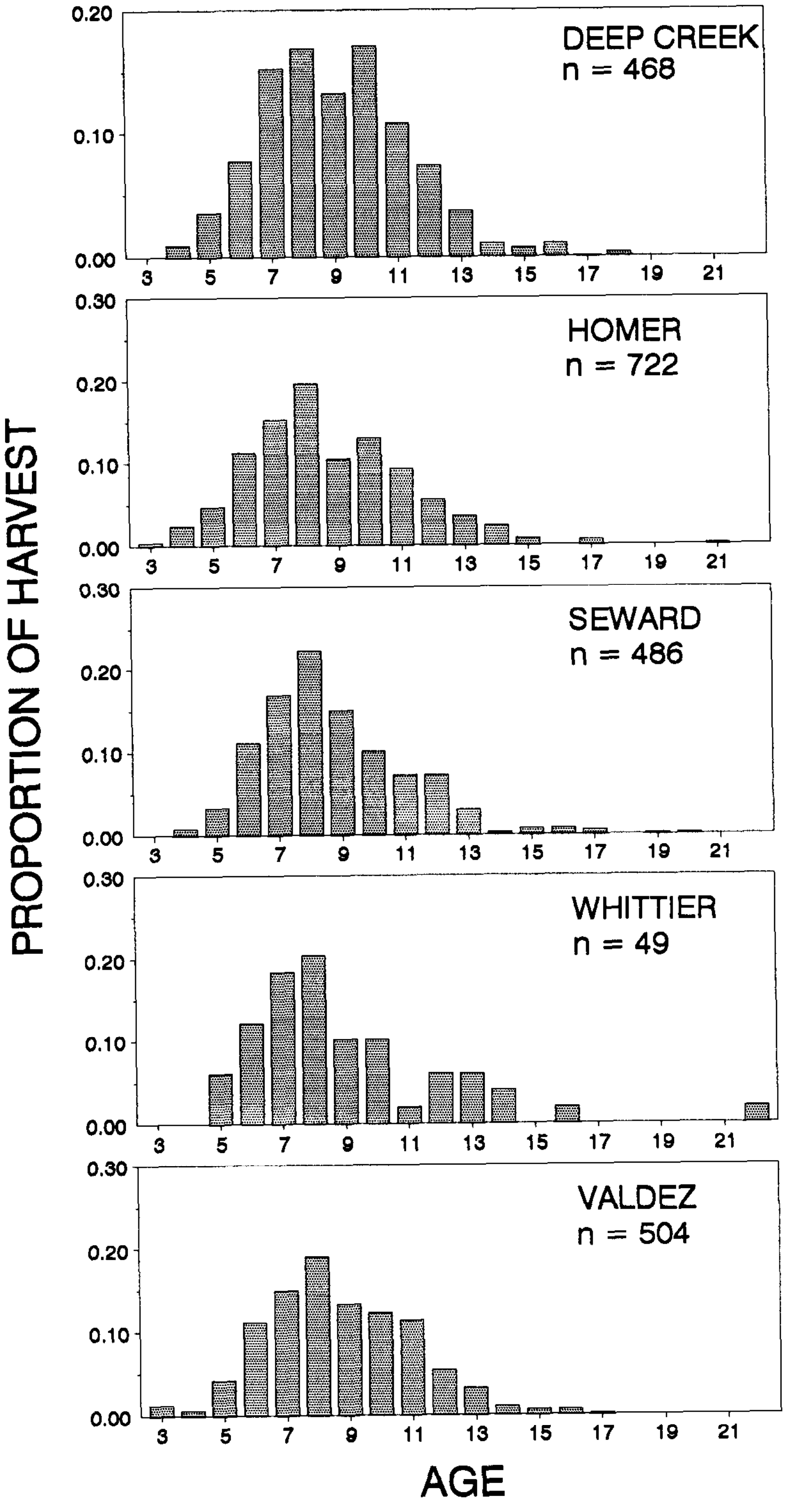

Figure 19. Estimated age composition of halibut harvested by sport anglers at Deep Creek, Homer, Seward, Whittier, and Valdez during the period May-September 1991.

Table 11. Numbers and proportions of boat interviews obtained each month at Deep Creek, Homer, and Valdez, 1991. The proportions were used as indicated in the far right column to weight monthly estimates of halibut age and size composition to produce estimates for the entire year.

Location	Month	Number of Interviews	Proportion	Weighting Factors Used	
Deep Creek	May	0	0		
	Jun	24	0.145	May-Jun	0.015
	Jul	85	0.512	Jul	0.512
	Aug	54	0.325	Aug-Sep	0.343
	Sep	3	0.018		
Homer	May	0	0	May	0.061
	Jun	49	0.174	Jun	0.113
	Jul	114	0.406	Jul	0.406
	Aug	104	0.370	Aug	0.370
	Sep	14	0.050	Sep	0.050
Valdez	Jun	38	0.207	Jun	0.207
	Jul	61	0.332	Jul	0.332
	Aug	75	0.408	Aug	0.408
	Sep	10	0.054	Sep	0.054

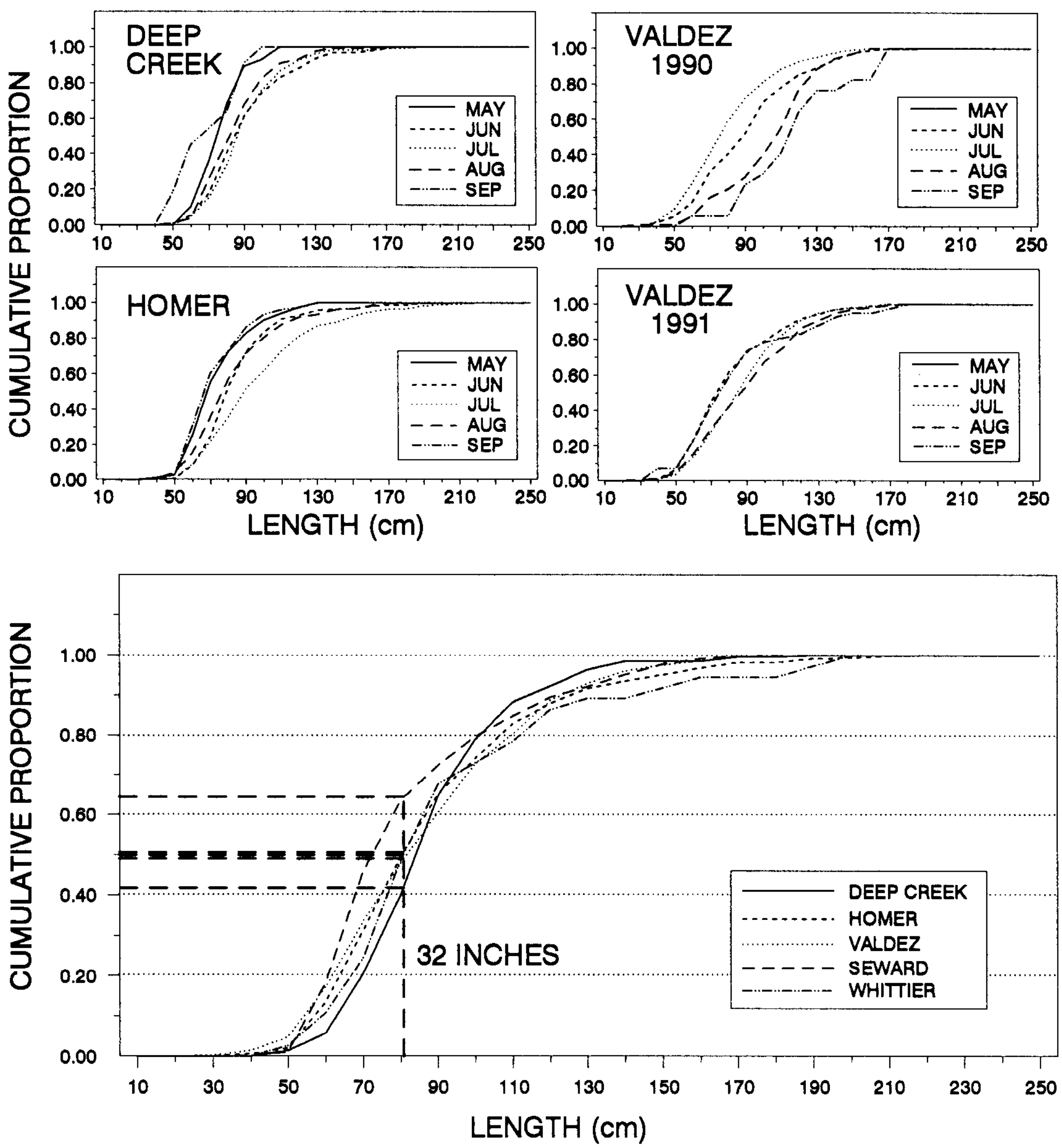

Figure 20. Estimated length composition (cumulative frequency distributions) of halibut harvested by sport anglers in Southcentral Alaska in 1991. Upper graphs show seasonal trends in length composition that were evident at Deep Creek and Homer in 1991, and at Valdez in 1990 and 1991. Dotted lines indicate the proportion of halibut under the commercial minimum size limit of 32 inches.

same potential bias noted above for age composition. Because no trends in size composition were evident at Seward or Whittier, monthly samples from these sites were pooled without weighting to estimate size composition for the year. The modal lengths of harvested halibut ranged from 70 cm to 99 cm. Recruitment to the sport fishery occurs at lengths of 30 cm-70 cm. The proportions of fish harvested by sport anglers that were under the commercial minimum size limit of 32 inches (81.3 cm) varied by site. These proportions ranged from 42% at Deep Creek to 65% at Seward (Figure 20). The proportion of the harvest under 32 inches for all of Southcentral Alaska could not be calculated without estimates of the number of fish harvested at each site.

Female halibut dominated the sport harvest at all ports and in all months (Table 12). Tests for differences in sex ratio between June, July, August, and September were not significant for Deep Creek ($\chi^2 = 1.723$, $P = 0.632$, df = 3), Homer ($\chi^2 = 0.525$, $P = 0.913$, df = 3), or Seward ($\chi^2 = 7.336$, $P = 0.062$, df = 3). At Valdez, sex composition did not differ between June, July, and August ($\chi^2 = 4.083$, $P = 0.130$, df = 2), but the proportion of females in the harvest was significantly lower in September. Sample sizes were inadequate for estimation of sex composition at Whittier. Differences in sex composition between ports were significant ($\chi^2 = 122.005$, $P < 0.001$, df = 3).

Mean Length at Age:

Data from all ports were pooled to estimate mean length at age of halibut of known sex. No appreciable trends or differences in size at age were apparent from plots of mean length at age by month. However, when data from all months were pooled, size at age of female halibut was curved distinctly upward. To avoid possible within-year growth effects, only July data are presented to describe the growth pattern. Female halibut were larger at all ages and grew faster than males (Figure 21). Growth of both sexes appeared to be approximately linear with slight upward curvature in females.

Spatial Distribution of Fishing Effort

Information on the spatial distribution of fishing effort was gathered from 829 interviews with private boat anglers and charter boat skippers and deck hands. Since most anglers were interviewed in conjunction with fish sampling, successful anglers probably had a greater chance of being interviewed. This was probably not a serious source of error, however. Catch rates were typically high enough that few boats returned without any fish. For example, in 1989 an average of 8.26 halibut were harvested per boat trip at Homer (Roth 1990).

Boats originating at Deep Creek (166 interviews) fished almost exclusively north of the latitude of Anchor Point (Figure 22). By contrast, the Homer fleet fished almost exclusively south of Anchor Point (276 interviews). Private boats from Homer split their effort about evenly between Kachemak Bay and waters westward, rarely venturing south of Point Adam. Larger charter boats generally fished farther from port. Effort by charter boats was evenly split between waters outside Kachemak Bay and waters south of Point Adam (Figure 22). Large charter boats occasionally fish as far south as the Barren Islands and as far east as Port Dick. It was not possible to construct a map showing the distribution of fishing effort by all boats in lower Cook Inlet.

Table 12. Estimated sex composition (proportion female) of halibut harvested at Deep Creek, Homer, Seward, Whittier, and Valdez in 1991. Only fish of known sex were included in computation of estimated proportions.

Site	Month	Number Sexed	Number Female	Proportion Female (p)	SE(p)
Deep Creek	Jun	71	63	0.89	0.038
	Jul	156	129	0.83	0.030
	Aug	154	131	0.85	0.029
	Sep	11	10	0.91	0.091
	Total	392	333	0.85	0.018
Homer	Jun	28	24	0.86	0.067
	Jul	168	142	0.85	0.028
	Aug	230	194	0.84	0.024
	Sep	102	89	0.87	0.033
	Total	528	449	0.85	0.016
Seward	Jun	8	5	0.63	0.183
	Jul	150	78	0.52	0.041
	Aug	273	172	0.63	0.029
	Sep	42	30	0.71	0.071
	Total	473	285	0.60	0.023
Valdez	Jun	393	310	0.79	0.021
	Jul	608	492	0.81	0.016
	Aug	409	345	0.84	0.018
	Sep	36	22	0.61	0.082
	Total	1,446	1,169	0.81	0.010

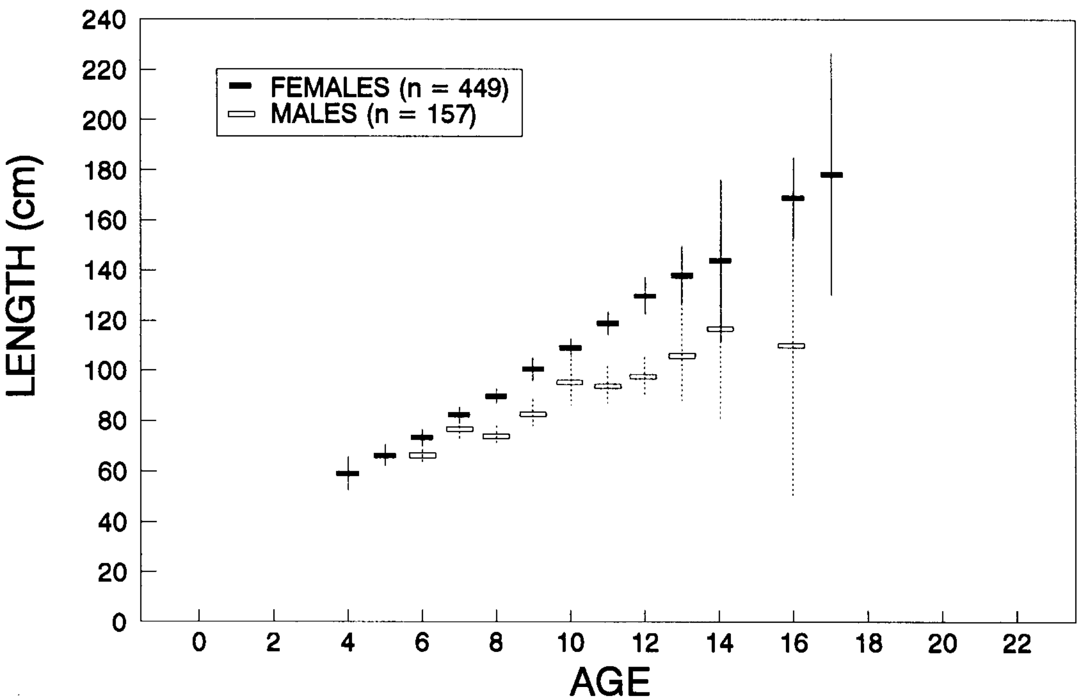

Figure 21. Estimated mean length at age of male and female halibut harvested by sport anglers at Deep Creek, Homer, Seward, Whittier, and Valdez during July 1991. Vertical bars represent 95% confidence intervals for mean lengths.

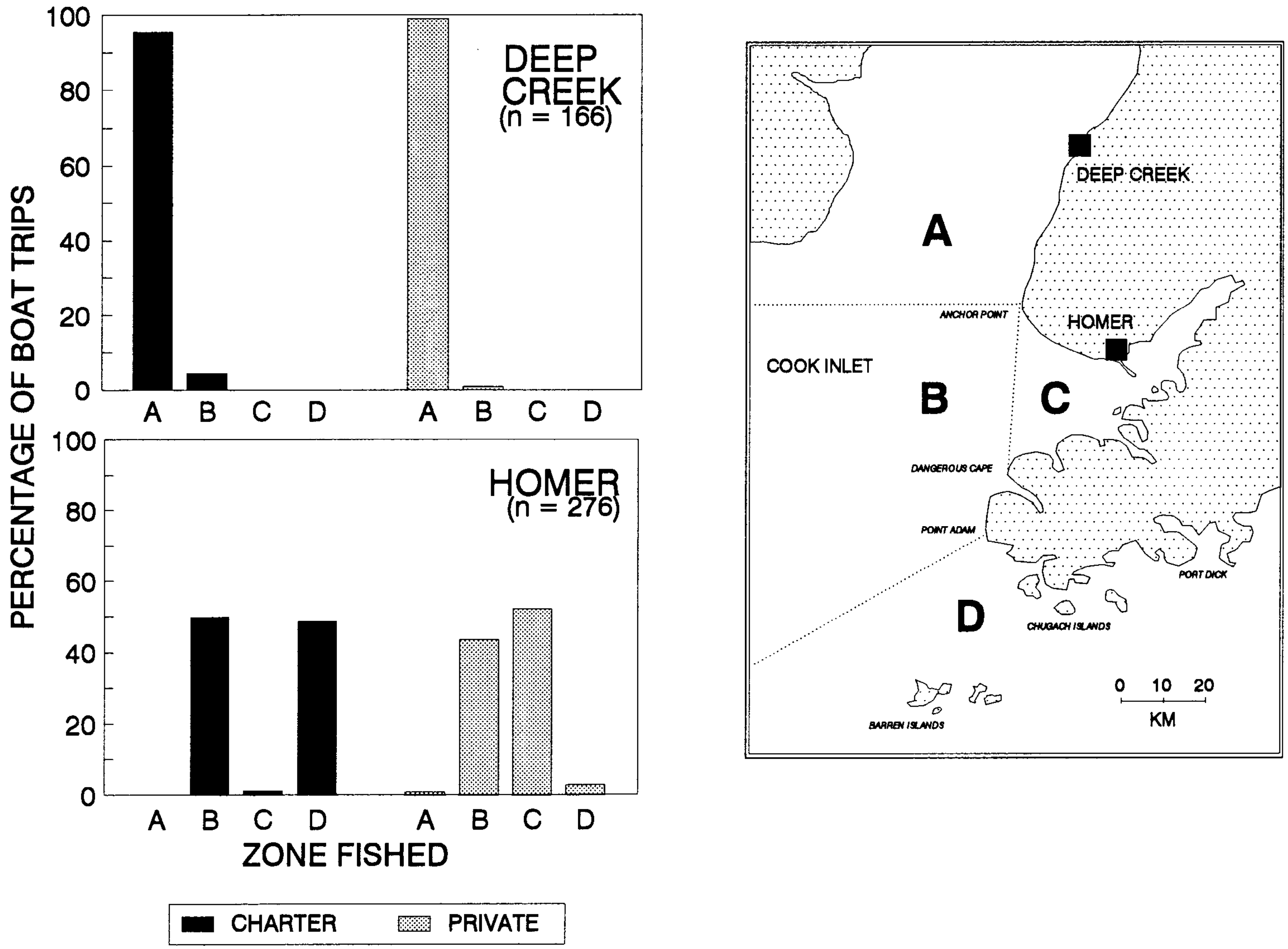

Figure 22. Estimated distribution of effort for groundfishes in lower Cook Inlet and the Gulf of Alaska by the Deep Creek and Homer sport fleets in 1991.

Interviews were not obtained at Deep Creek and Homer in proportion to the amount of effort at each site. In addition, interviews were not obtained from any boats launched at Anchor Point, Ninilchik, Whiskey Gulch, Tutka Bay, or the Seldovia-Port Graham area.

Fishing effort by Seward private and charter boats was widespread over Gulf of Alaska waters from Harris Point eastward to Cape Puget (150 interviews). Most effort was concentrated around Aialik Cape and islands near the mouth of Resurrection Bay (Figure 23). Private boats were generally smaller and fished closer to port than charter boats. About 84% of private boat trips were inside of a line running from Aialik Cape to Cape Mansfield. By comparison, 63% of charter boats fished in the same area and 19% fished waters east of Cape Mansfield. Information on the distribution of effort was not available for charter boats from the military recreation camps, but conversations with military boat operators indicated that their effort was distributed similarly to the rest of the fleet with infrequent excursions westward to the Pye Islands. The military fleet of 16 boats makes up a significant portion of the total effort and harvest.

Although only 53 interviews were obtained in Whittier, this probably represented a large fraction of the effort. The Whittier fleet fished exclusively in western Prince William Sound. Effort was spread as far south as Elrington Island but most anglers fished waters closer to Whittier. Effort was concentrated in waters near Esther Island, Culross Island, and Perry Island (Figure 24).

Boats interviewed at Valdez (n = 184) fished throughout most of eastern and central Prince William Sound. Effort was spread west to Perry Island and Knight Island, east through Port Gravina, and south to Hinchinbrook Entrance. The highest concentration of effort was in areas near Bligh Island and Knowles Head (Figure 25). As expected, private boats fished closer to port than charter boats. About 62% of private boat trips were north of Goose Island and east of Glacier Island. Only 18% of charter boat trips were in that same area, while 38% were in waters around Hinchinbrook Island. Many charter boat captains prefer waters near Hinchinbrook Entrance for halibut, but travel to that area was often limited by bad weather.

DISCUSSION

This report presents the most comprehensive biological data yet collected for most of the major groundfish sport fisheries in Southcentral Alaska. Previous studies either focused on one fishery (Roth and Delaney 1989, Vincent-Lang 1991) or collected more fishery performance data rather than biological data (Roth 1990). Inferences about stock status based on these results should take into account an important limitation of the data--namely that these are harvest data only, from a fishery that can be selective for certain species, ages, sizes, etc. The nature of selectivity by the sport fishery is largely unknown because fishery-independent survey data are not available for comparisons. In spite of this limitation, relative changes in biological characteristics should be indicative of trends in the population as long as the same stock or stocks are harvested year after year, and there are no substantial changes in the preferred sizes of fish harvested.

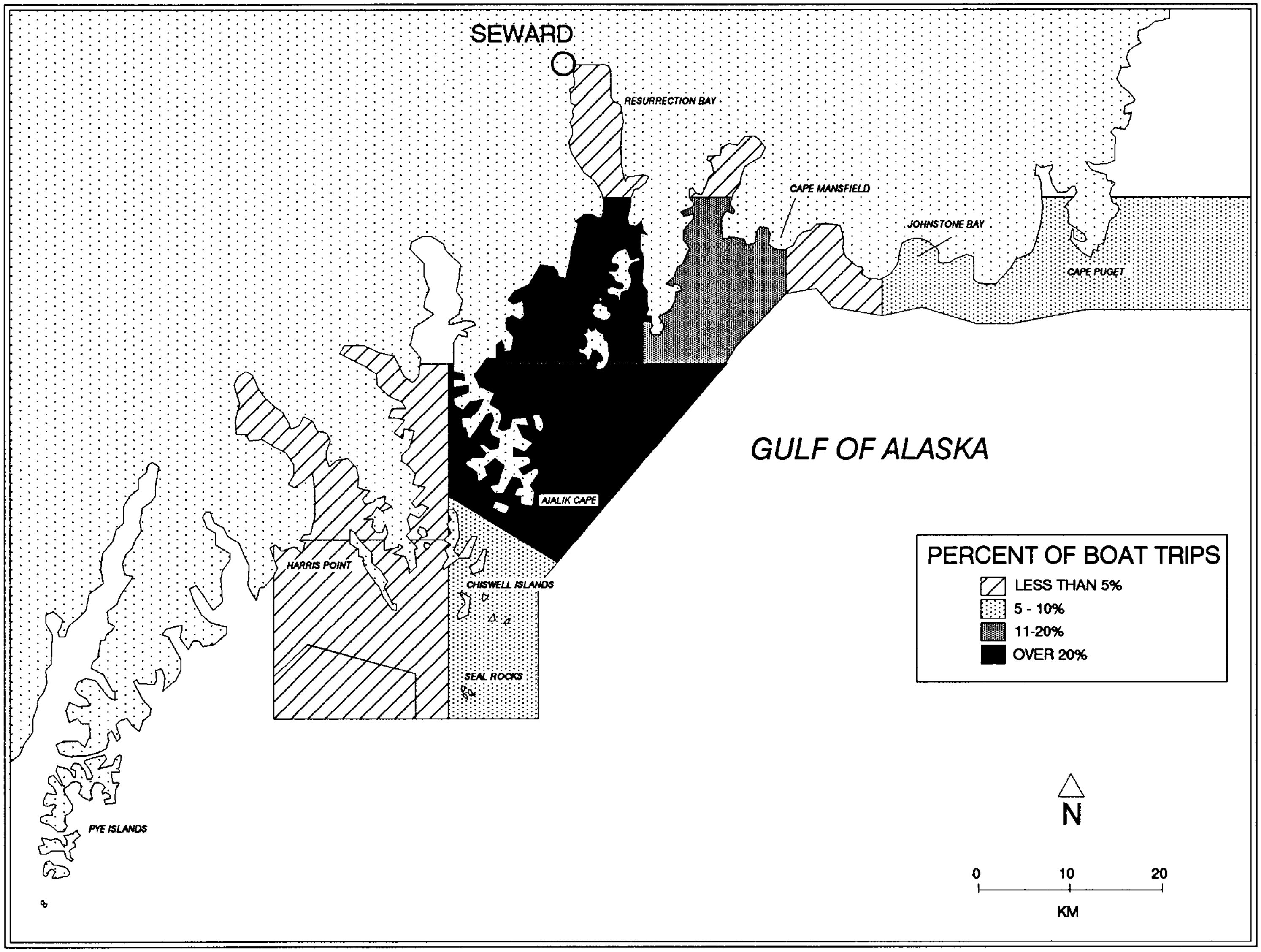

Figure 23. Estimated distribution of effort for groundfishes in the Gulf of Alaska by the Seward private and charter sport fleet in 1991. Information was not available for military recreation camp boats (see text).

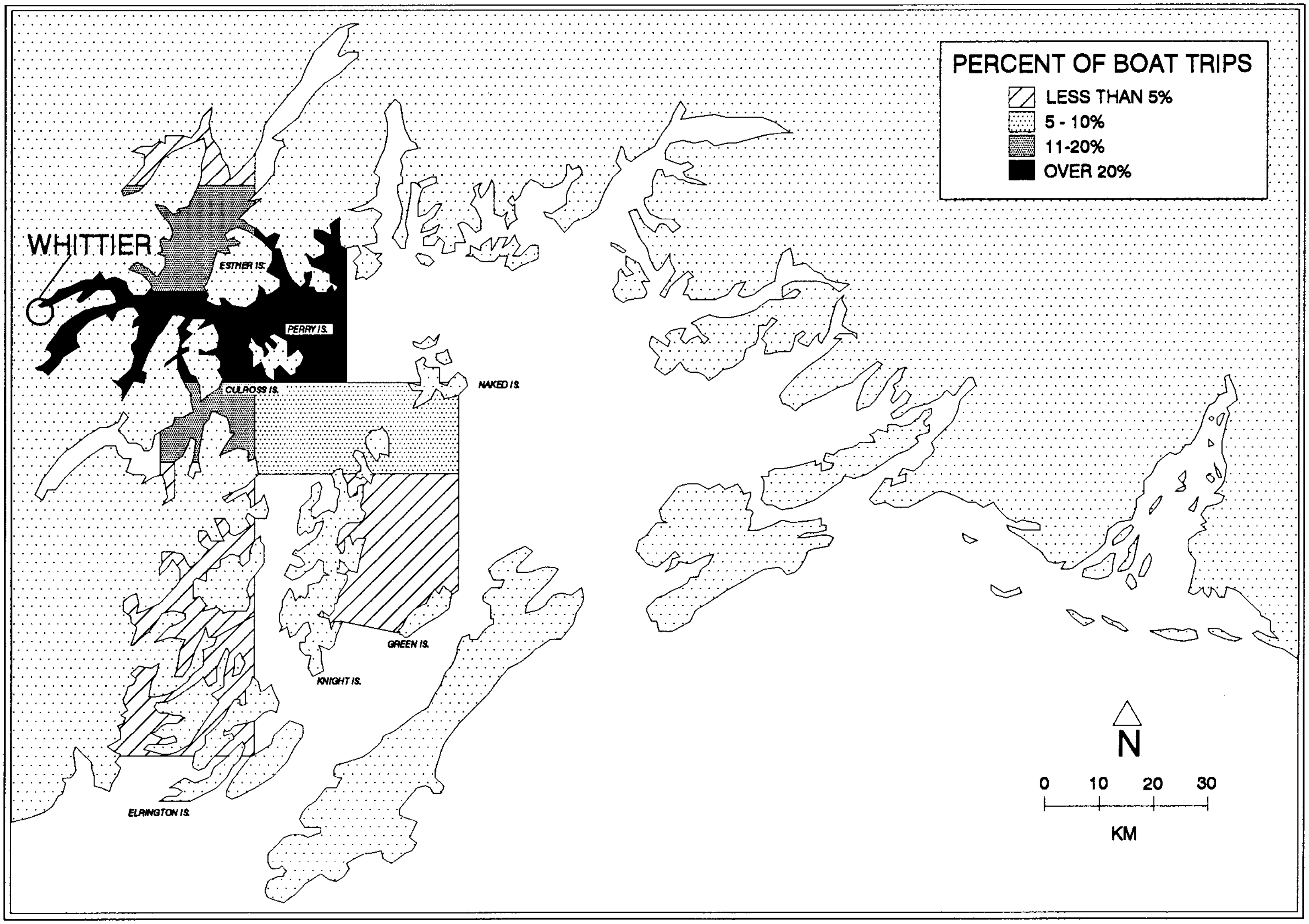

Figure 24. Estimated distribution of effort for groundfishes in Prince William Sound by the Whittier sport fleet in 1991.

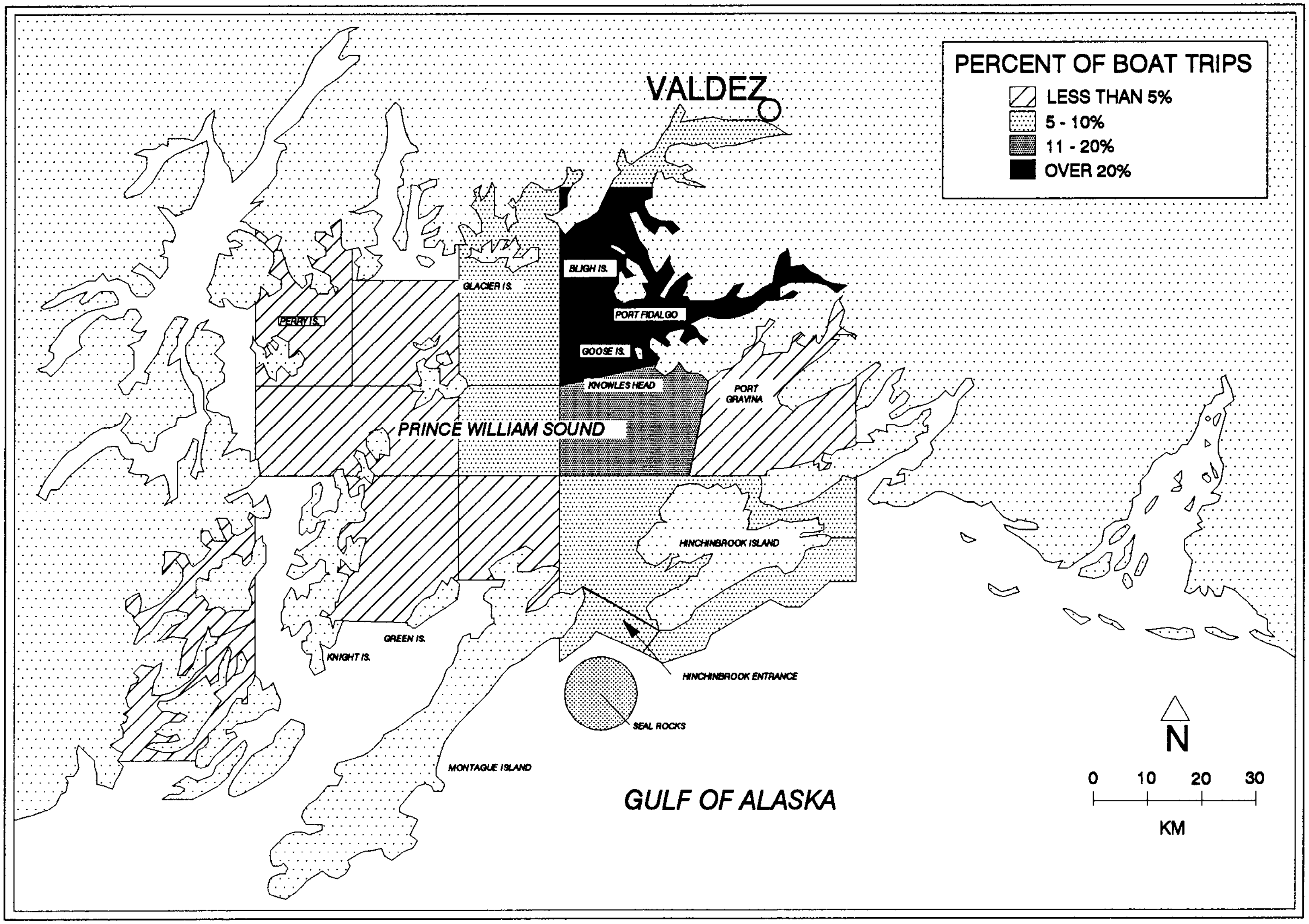

Figure 25. Estimated distribution of effort for groundfishes in Prince William Sound by the Valdez sport fleet in 1991.

Rockfishes

Black and yelloweye rockfish are clearly the two most important species to sport anglers as they dominated the harvest at all ports (Figure 5). The high proportion of black rockfish in the Seward harvest is largely due to the directed fishery that has focused on this species since the early 1960s (Logan 1971). The high proportion of black rockfish in other harvests is probably due to their ease of capture and high relative abundance in shallow nearshore areas (Rosenthal 1980).

Species composition of the sport rockfish harvest was variable between months (Table 5) and between years at Valdez (Figure 5) and Seward (Table 13). This variation was probably due to a combination of unknown seasonal movements and changes in fishery patterns. Limited studies in Prince William Sound (PWS) showed that rockfishes moved out of nearshore areas in the fall and returned in spring (Rosenthal 1980), but are generally thought to be stationary during the summer months. Fishery factors that could affect species composition include changes in desired species and the spatial distribution of fishing effort. Future sampling should clarify the interannual variability in rockfish species composition. Conclusions regarding the relative abundance of different rockfishes should not be based solely on species composition data.

Comparisons of rockfish age and length estimates between areas raise some interesting questions. There was no apparent pattern to observed differences in age, length, or size at age of black rockfish between locations (Figures 6, 7, and 11). On the other hand, yelloweye rockfish recruit at least 5 years earlier (Figure 8) and at a smaller size (Figure 9) in PWS than in the Gulf of Alaska. Fish from PWS also appear to grow more slowly (Figure 11). Reduced growth in PWS could be due to lower water temperatures, lower salinity, or higher turbidity resulting from glacial melt. Because the data are from harvested fish only, numerous explanations can be offered for the earlier recruitment in PWS. For example, the relatively high abundance of 10- to 20-year-old fish in the PWS harvest could have been due to either strong recruitment (and lack of recruitment in the Gulf of Alaska) or overharvest of older fish, leaving younger ones to make up a greater portion of the harvest. Differences in age at recruitment may also be a result of location (depth, distance from shore) of harvest in relation to the spatial segregation of different age or size classes. Field (1984) found in Southeast Alaska that juvenile pelagic rockfishes were more common in catches near shore and that the mean length of fish caught increased with depth. Although yelloweye rockfish are not pelagic, this could also hold true for demersal species. It is possible that the PWS fishery concentrates more on shallow waters or that smaller fish are uncommon in areas fished near Seward and Homer. Previously unreported creel survey data from 1973 was examined for historical changes in the spatial distribution of harvest. Comparison with 1991 data indicates that fishing effort has spread farther from Seward, supporting the idea that at least some anglers are moving to maintain high catch rates (Figure 26). Yelloweye rockfish from these previously lightly fished areas may be larger and older, explaining at least some of the differences in age and size composition. Another possible explanation is that anglers at Seward and Homer selectively keep larger fish.

Conclusions regarding changes in stock status that are based on changes in age distributions should take into account the resolution of the data. Within and

Table 13. Changes in species composition of the primary rockfishes harvested at Seward, 1989-1991[a].

Year	n	Species	Species Proportion by Month				Total
			Jun	Jul	Aug	Sep	
1989	873	Black	0.55	0.68	0.68	0.88	0.70
		Yelloweye	0.39	0.22	0.18	0.06	0.21
		Other	0.06	0.10	0.14	0.06	0.09
1990	1,259	Black	0.53	0.55	0.58	0.60	0.55
		Yelloweye	0.39	0.27	0.27	0.29	0.32
		Other	0.08	0.18	0.15	0.11	0.13
1991	1,655	Black	0.69	0.66	0.66	0.81	0.68
		Yelloweye	0.25	0.26	0.25	0.08	0.23
		Other	0.06	0.08	0.09	0.11	0.09

[a] Data from 1989 and 1990 are from Vincent-Lang (1991).

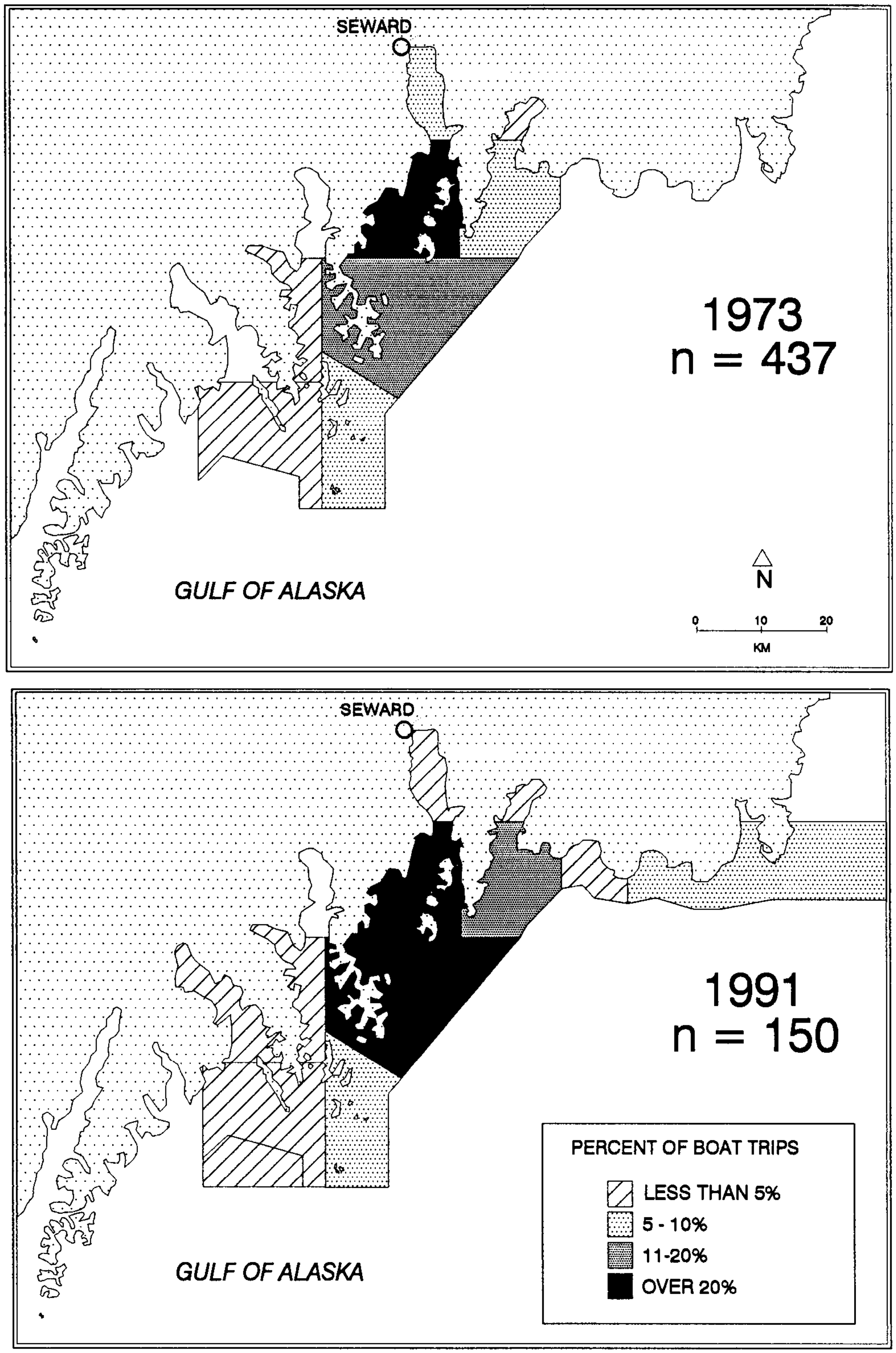

Figure 26. Expansion of sport fishing effort for groundfish by the Seward fleet between 1973 and 1991.

between-ager errors using the break-and-burn technique employed can range up to ∓5 years. Between-reader variability in rockfish ages was not rigorously assessed in this study, but comparison of age distributions from past years suggests there may have been between-year drift in the criteria used to assign ages. Between 1989 and 1990, the mode of the black rockfish age distributions for Seward shifted 2 years from age 10 to 12 (Figure 27). In addition, this mode was extremely pronounced both years, accounting for about 25% to 32% of the harvest. Assuming for a moment that the age 12 mode in 1990 was correctly aged, a relatively strong mode at age 13 would be expected in 1991. This age class, however, did not materialize and was in fact relatively weak.

Comparisons of yelloweye rockfish age compositions between successive years show a similar trend--a strong mode including ages 20-22 shifted to ages 24-26 by 1991, a difference of 4 years in a span of only 2 years (Figure 28). More rigorous assessment of variability in rockfish ageing will be necessary if these data are used in statistical models to predict harvestable surplus. Not too much emphasis should be placed in minor shifts in age composition until ageing errors are better understood.

Estimates of rockfish mortality rates should be viewed with caution. Unbiased estimation of mortality relied on compliance with several restrictive assumptions (see methods). Besides suspected errors in ageing, one of the most likely violations was that the sample was not representative of the age groups in question. Since the size of black rockfish caught was largely independent of age (Figure 11), it is likely that the sport fishery was not size-selective and that estimates of age composition were representative. The sport fishery could be selective on the basis of age, however, if older black rockfish inhabit waters not sampled by the fishery (e.g. deeper, farther offshore). Estimated mortality rates of yelloweye rockfish were slightly higher than estimates reported for commercially caught fish in Southeast Alaska (O'Connell et al. 1991). This difference could have been due to selectivity by the sport fishery for smaller, younger fish. If size and age are positively correlated with depth, then the sport fishery would be selective for younger fish because of the difficulty in fishing deep waters. Older yelloweye rockfish were relatively more abundant in age frequency distributions from commercial catches near Seward (Vincent-Lang 1991) and in Southeast Alaska (O'Connell and Funk 1986) in the early 1980s.

Although sport harvest data are not unbiased, several conclusions can be drawn concerning rockfish fisheries and stocks in Southcentral Alaska. First, black and yelloweye rockfish are by far the most important species in the sport harvest. Other species such as quillback, copper, and silvergray rockfish make up smaller proportions of the harvest and are probably also less abundant. Second, there appear to be regional differences in age, size, and growth of adult yelloweye rockfish that suggest segregation of PWS and Gulf of Alaska stocks. Third, black rockfish have much higher mortality and growth rates than yelloweye rockfish, suggesting a higher potential yield.

Although data are lacking to recommend acceptable rates of sustainable harvest, one thing is clear--because of their high longevity and low rates of production, the risk of overharvest is high. Because rockfishes have much lower rates of production compared with most other commercial species (Francis 1985), the consequences of overharvest are also long-lasting. Rockfish fisheries typically develop rapidly and rely on relatively high standing

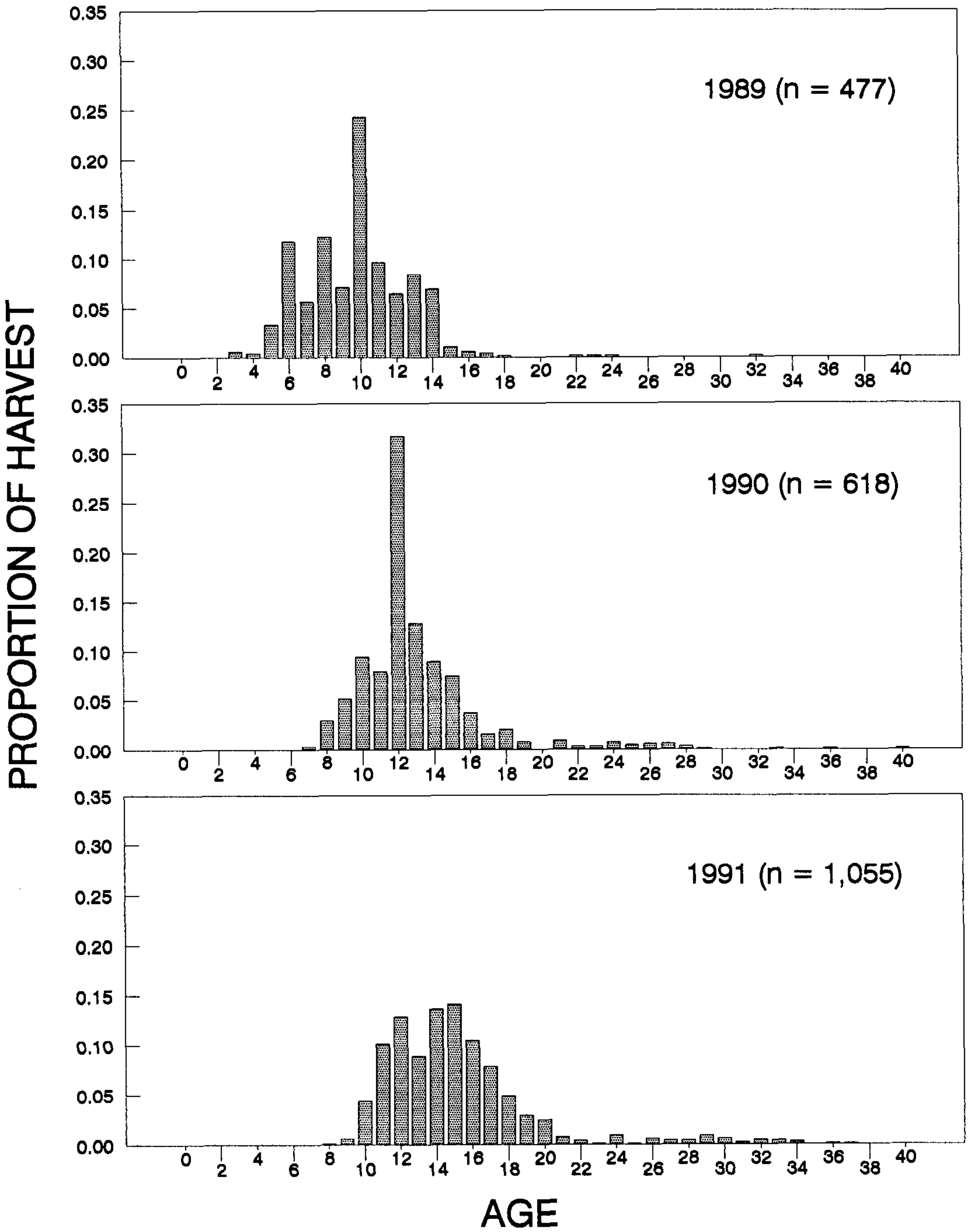

Figure 27. Shifts in age composition of black rockfish harvested by sport anglers at Seward between 1989 and 1991. The 1989 and 1990 data are from Vincent-Lang (1991).

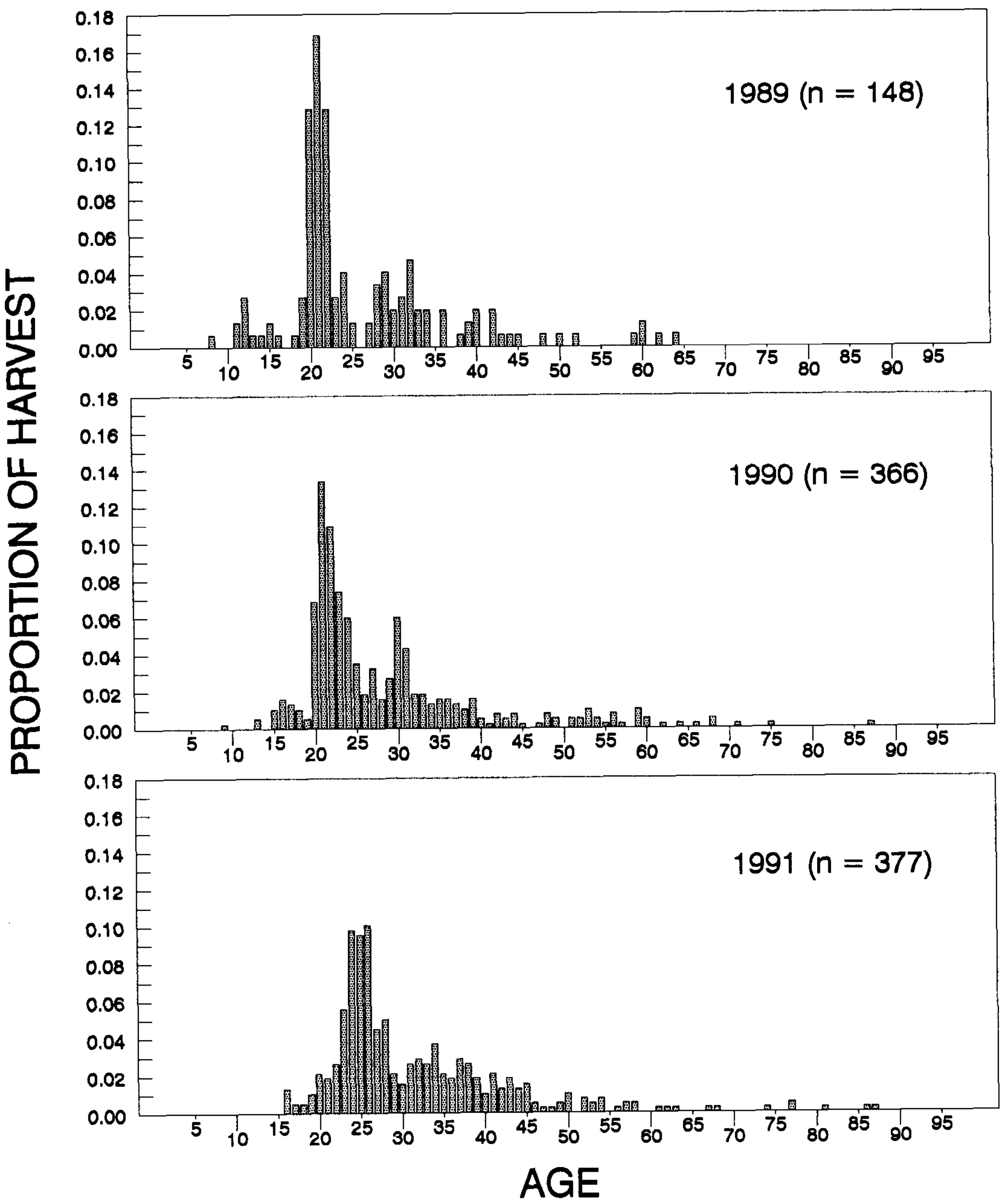

Figure 28. Shifts in age composition of yelloweye rockfish harvested by sport anglers at Seward between 1989 and 1991. The 1989 and 1990 data are from Vincent-Lang (1991).

stocks rather than annual production. As the fleet moves to sustain high catch rates, stocks can be harvested down to levels at which productivity of the stock is destroyed (Francis 1985). Examples of such fisheries include the Gulf of Alaska foreign trawl fishery for Pacific ocean perch (Bracken 1986), the southeastern Alaska demersal rockfish fishery (Bracken 1989), and the Oregon coast sport fishery for black rockfish (PFMC 1991). Clearly, fishery managers must take a conservative approach to rockfish management until more information becomes available.

Bracken (1988) discussed numerous possible approaches to conservative rockfish management. Restrictive bag limits and area and season closures are among the most suitable regulations for sport fisheries. Restrictive bag limits may not provide for sustained harvest of demersal rockfish if the fish are bycatch in other directed fisheries (e.g. halibut and lingcod). If effort is high enough, even incidental mortality of released fish could exceed sustainable levels of fishing mortality. At least two types of area closures should be considered. One approach could be to identify and designate marine sanctuaries. These would be the most valuable areas for reproduction and recruitment and would be permanently closed to all fisheries. The effectiveness of this approach is unknown because of the lack of data regarding larval drift and recruitment mechanisms. A second approach would be to implement a rotational harvest strategy. Certain zones would be open to harvest for specified periods or until a harvest quota was reached. As Bracken (1988) pointed out, a major drawback of this method is that the time needed to rebuild depleted stocks would be too great for practical management.

<u>Lingcod</u>

Sport harvest of lingcod in Prince William Sound and in lower Cook Inlet is minimal. In the Seward-based sport fishery, however, there is some cause for concern. Synthesis of all available data shows that as harvest is increasing, recruitment and adult abundance may be declining in Resurrection Bay and adjacent waters.

Age composition data collected from the Seward fishery since 1987 indicate that recruitment has been variable and may be decreasing. Variability is evident in the right hand limbs of age distributions from 1987 through 1991 (Figure 29). For example, the 1981 year class was exceptionally strong, accounting for 23%-28% of the sport harvest from 1987 through 1990. By 1991, the contribution of this year class (age 10) dropped to only 12%. The mode of the age distribution also shifted downward to age 7, with no single year class dominating the harvest. Another relatively strong year class appeared as 10-year-old fish in 1987. Weak recruitment in recent years is suggested by decreases in the relative proportions of 3-5 year-old fish. The strong showing of ages 7-9 in the 1991 harvest resulted from partial recruitment of 3-5 year-olds in 1987. Since 1987, the proportion of 3-5 year-old fish in the harvest decreased from 19.1% to only 1.4% in 1991 (Table 14). Length data indicate the same trend: the proportion of fish under 70 cm decreased from 18.7% to 1.3%. The corresponding changes in age and length distributions negate the possibility that the observed decline in recruiting age classes is the result of systematic ageing errors.

If recruitment is in fact declining, the cause is unknown. As noted earlier, variability in lingcod recruitment has been shown to be fishery-independent

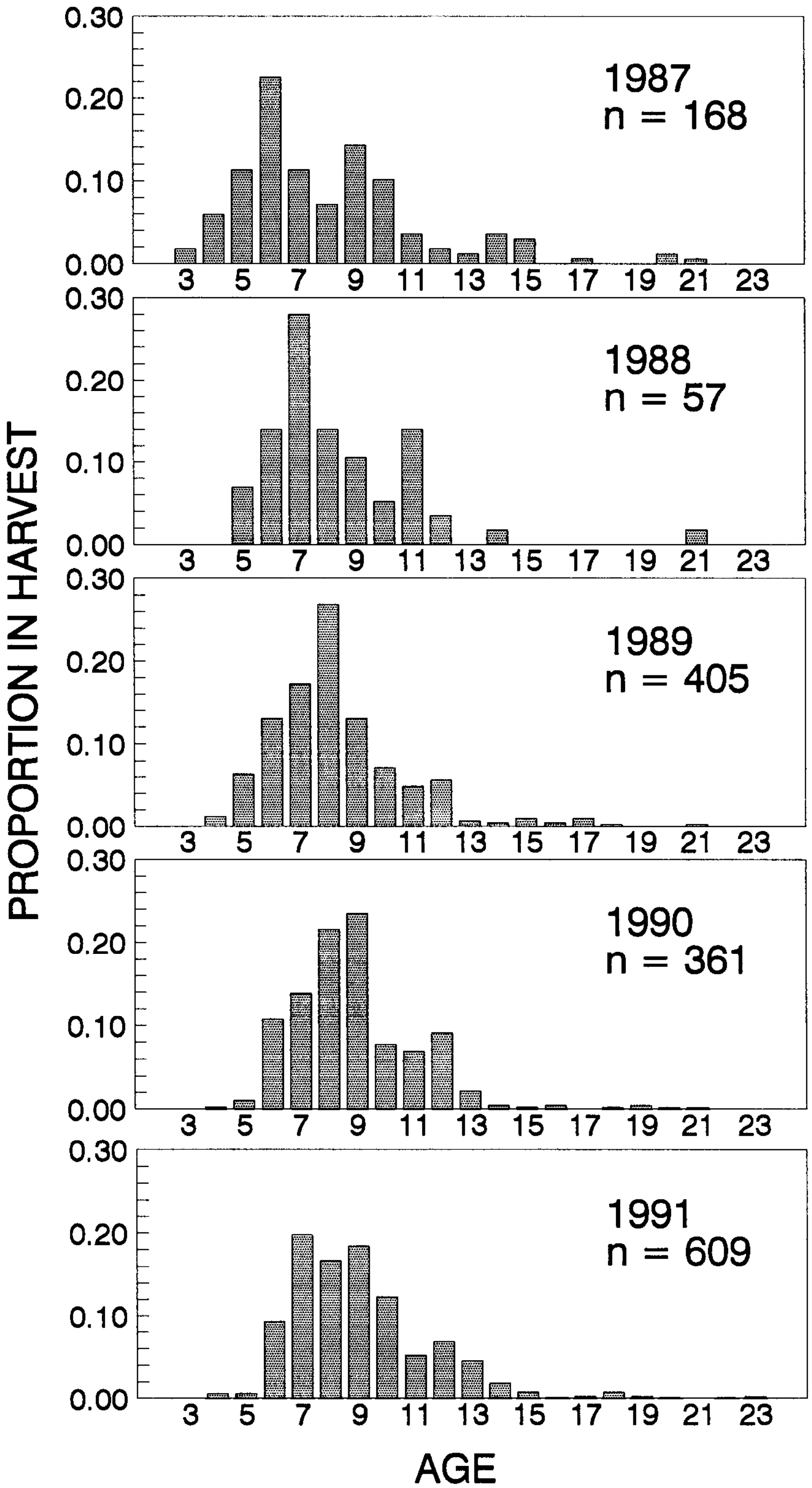

Figure 29. Age composition of lingcod harvested by sport anglers at Seward during the period 1987-1991. Data for 1987-1990 are from Vincent-Lang (1991).

Table 14. Decreases in the proportion of recruiting lingcod in the sport harvest at Seward during the period 1987-1991.

Year	Percentage of the Sport Harvest Under Age 6	Percentage of the Sport Harvest Under 70 cm
1987	19.1	18.7
1988	7.0	4.5
1989	7.5	11.3
1990	1.4	2.6
1991	1.4	1.3

(Bargmann 1982). Male lingcod are reportedly aggressive protectors of nests, and are therefore easy to catch. Removal of a nest-guarding male practically assures failure of that nest due to predation (Low and Beamish 1978). It is unlikely, however, that the fishery alone is responsible for declines in recruitment. The weak 3- to 5-year-old age classes observed in 1990 and 1991 resulted from the 1985-1988 brood years when sport and commercial harvests were presumably much lower than recent years. It is unlikely, therefore, that the fishery alone is responsible for declines in recruitment.

Vincent-Lang (1991) first proposed the possible decline in recruitment. It could also be argued that recruitment is not declining and that the harvest age structure is not representative of the population age structure. This could be caused by an increasing trend in the selective harvest of large fish. While there have been no reductions in the lingcod bag limit since 1987 that would cause selectivity, the fishery is rapidly developing and anglers may be increasing their skill at locating and catching large fish in areas not fully exploited in the past. Modern electronics capable of discerning individual fish are common on most charter boats and many private boats.

Evidence to support decreased abundance of adult lingcod includes anecdotal reports from the fishery and changes in the spatial distribution of fishing effort. Charter boat operators report drastic reductions in lingcod abundance in Resurrection Bay and around the Chiswell Islands in the last 5 years. Although the total sport harvest is increasing, harvest rates may not be indicative of abundance. Comparison of information on the distribution of effort with previously unreported creel survey data from 1973 shows that fishing effort has spread farther from Seward, indicating that at least some anglers are moving to maintain high catch rates (Figure 26).

Considerable uncertainty exists in the assessment of this fishery. Given the rapid development of the fishery and the evidence of possible decreases in recruitment and adult abundance near Seward, it would be prudent to enact measures to control harvest. Options that should be considered include seasonal closures, area closures, size limits, reduced bag limits, and combinations of these. A spring closure would protect nest-guarding males, helping to ensure future recruitment while reducing adult harvest. Area closures would allow for rebuilding of overharvested areas. Minimum-size limits could be employed to guarantee that all fish have the opportunity to spawn at least once prior to being harvested. Once harvest is brought under control, additional studies should be undertaken to define stocks and evaluate potential alternative management systems. More intensive management will also require monitoring and evaluation.

Halibut

The data gathered in 1991 revealed some important facets of halibut sport fisheries in Southcentral Alaska. The seasonal trends observed in age and size composition at Deep Creek, Homer, and Valdez can be explained by what is known about general seasonal movements. Most halibut spawn from November through March far offshore in about 100 fathoms (180 m) of water (St-Pierre 1984). Tagging studies have shown that these larger, mature halibut move onshore to feed in summer, then back offshore to spawn in the fall (Calvin Blood, IPHC, personal communication). The lack of seasonal trends in age and size of halibut harvested at Seward may be due to the proximity of the fishing grounds to spawning areas.

Comparisons of sport and commercial age data show that recruitment to the sport fishery was complete by age 8 compared with age 11 for commercial harvest in Area 3A, the central Gulf of Alaska (Figure 30). Much of this difference is explained by the commercial minimum size limit of 32 inches (81.3 cm). The 1982 year class (age 9) appeared relatively weak in both sport and commercial age distributions. This point supports concurrence of ages determined by ADF&G and IPHC personnel.

The high proportion of females in the harvest was surprising given that males are typically smaller than females, and that most of the harvest was within the size range of males. One possible explanation for the higher percentage of males observed at Seward could be proximity to deeper water and a preference for depth by males. In support of this idea, females made up 83% of the sport harvest at Newport, Oregon, but only 52% of the harvest at Neah Bay, Washington (Blood 1992a). Neah Bay is much closer to known spawning grounds (St-Pierre 1984) and deep water than Newport. The sex ratios of sport and commercial harvests cannot be compared because commercial-caught halibut are typically eviscerated prior to landing.

The linear growth pattern observed from sport-caught halibut (Figure 21) concurs with size at age data from the commercial fishery (Blood 1992b). The slight upward curvature evident in the growth of females could be explained by recent decreases in the growth rate of halibut. This reduction in growth has prompted the IPHC to investigate the possibility of recommending a reduction in the minimum size limit of halibut for 1993 (Clark 1992).

Halibut stocks are declining as part of a long-term cycle in abundance (Sullivan 1992). The stock is expected to continue declining at a rate of about 5%-10% per year over the next several years. In the face of this decline, the sport harvest appears to be steadily increasing. Although increasing, the sport harvest still makes up a minor portion (11%) of all removals in Southcentral Alaska, and much less than commercial harvest and bycatch (Table 15). Increases in sport effort and harvest have caused the IPHC to begin incorporating sport harvest data in their stock assessment models. In 1991, the IPHC included estimated removals by sport fisheries and wastage due to gear loss. This resulted in a 10%-15% increase in annual catch and a 10% increase in estimated biomass in recent years (Sullivan 1992).

Increases in sport harvests have also prompted the IPHC to consider institution of minimum size limits for all sport fisheries. Minimum size limits ranging from 32 to 50 inches are currently in effect from California to British Columbia. One possible effect of a minimum size limit on the Southcentral Alaska sport fishery would be an increase in the total biomass removed. Anglers in IPHC Regulatory Area 3A released 46% of the halibut they caught in 1990 (Table 16). This ratio was corroborated by an on-site creel survey that found boat anglers targeting groundfish released 37.4% of the halibut they caught in the 1988 Valdez fishery (Roth and Delaney 1989). High catch rates may allow anglers to achieve their daily bag limit of larger fish, thus increasing the total weight of the harvest.

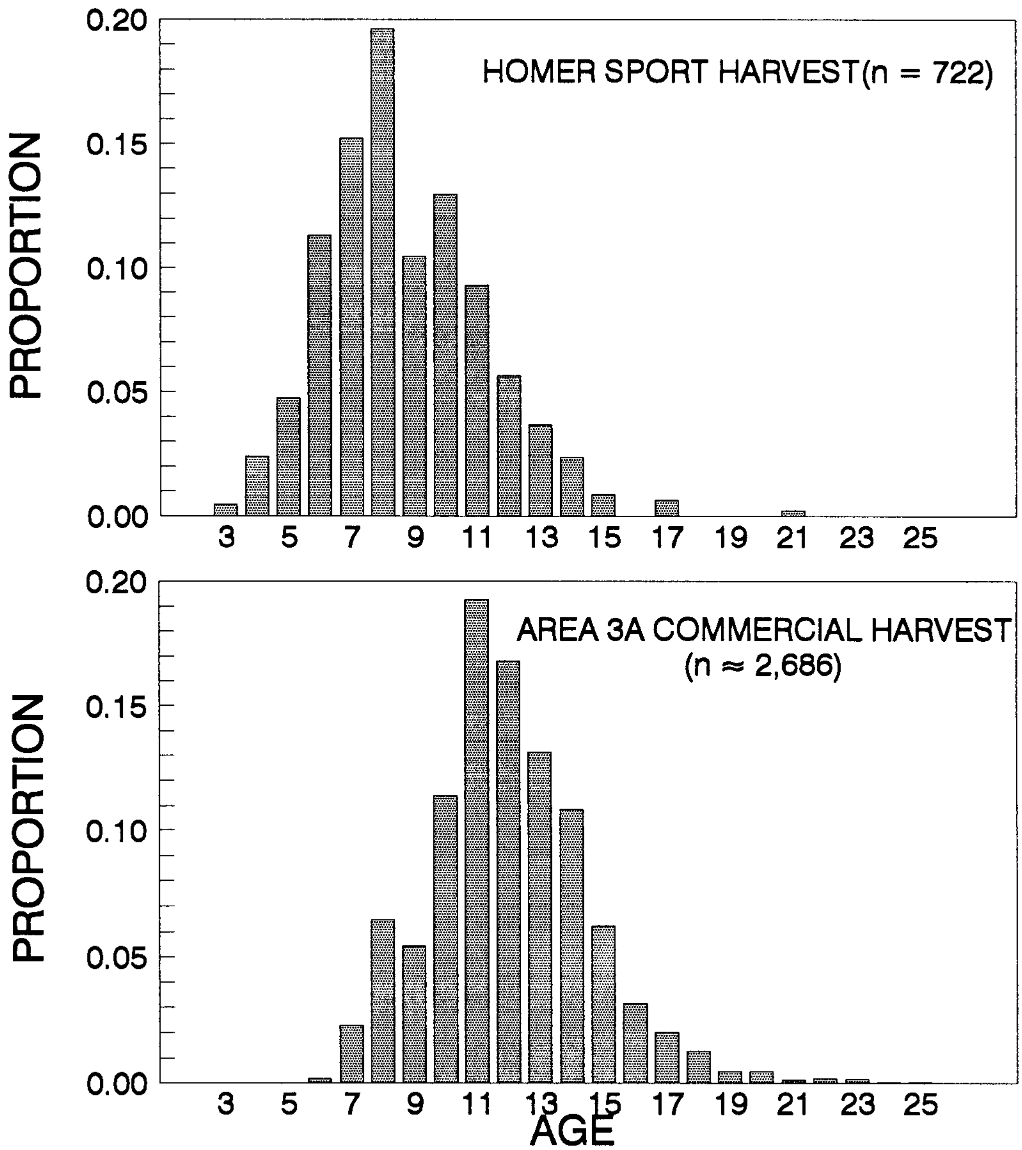

Figure 30. Comparison of sport and commercial age composition of Pacific halibut landed in Southcentral Alaska in 1991. The sport data are from Homer, the largest sport fishery, and commercial data are from throughout IPHC Regulatory Area 3A (Blood 1992b).

Table 15. Estimated removals of halibut in IPHC Regulatory Area 3A in 1991.

Source of Removal	Million Pounds	Percentage
Commercial harvest	23.60	67.7
Commercial bycatch	5.00[a]	14.4
Sport harvest	3.75	10.7
Wastage[b]	1.54	4.4
Subsistence	0.96	2.8
Total	34.85	

[a] The total bycatch mortality was estimated at 5.76 million pounds for regulatory Areas 3A and 3B combined. The 5.00 million pounds reported here is an approximation (P. Sullivan, IPHC, personal communication).

[b] Includes sub-legal size discard and estimated legal-size fish killed on lost or abandoned gear.

Table 16. Estimated proportions of halibut kept and released by sport anglers (Mills 1991).

Location	Number Caught	Number Harvested	Percent Kept	Percent Released
Yakutat	2,052	1,459	71.1	28.9
Prince William Sound	18,897	10,851	57.4	42.6
Kenai Peninsula[a]	294,230	156,353	53.1	46.9
West Cook Inlet	2,906	1,685	58.0	42.0
Kodiak	16,846	9,134	54.2	45.8
TOTAL	334,931	179,482	53.6	46.4

[a] Includes Deep Creek, Homer, and Seward.

The IPHC intends to begin incorporating age, size, and sex composition as well as catch rate data from the sport fishery into their stock assessment models (R. Trumble, IPHC, personal communication). This project already collects all but the catch rate data. Sport fishery catch rates should be used with caution as an index of halibut abundance. One reason is that catch rates of charter boats are typically higher than private boats. Charter boats in Homer accounted for 48% of the effort (for all species) but 66% of the halibut harvest in 1990 (Mills 1991). The catch rate of chartered anglers in Valdez was five times the catch rate of unchartered anglers in 1988 (Roth and Delaney 1989). Another reason is that catch rates by the sport fleet may not be representative of abundance because of changes in the availability of halibut. This report showed seasonal changes in age and size composition that are probably related to fish movement. These seasonal changes were different at Valdez in 1990 and 1991 (Figure 20), suggesting that availability of halibut may change from year to year.

RESEARCH RECOMMENDATIONS

Rockfishes and Lingcod

Effective management of rockfishes and lingcod will require more information than is currently available or collected through the existing sampling program. As mentioned above, a major drawback to looking at only harvest data is that it may not be representative of the population because of gear selectivity, preference by anglers for certain species or sizes, and uneven distribution of effort and harvest. Scientific surveys utilizing a random sampling design and a variety of gear types could provide unbiased information. Even if biased, this information could be compared to sport and commercial harvest data to quantify selectivity.

One of the first steps to improved management should be definition of unit stocks. A group of fish can be treated as a unit stock if conclusions drawn from the data do not depart substantially from reality due to differences within the group and interchanges with other groups (Gulland 1983; pp. 21-22). The extent of rockfish and lingcod movement between areas is unknown. At least some seasonal congregations of certain species or sexes are suspected. The evaluation of intensive management of these species would benefit greatly from unit stock definition. For example, the effectiveness of area closures, sanctuaries, or rotational harvests would depend on the degree to which fish would move between harvest and nonharvest areas. Information on stock definition could be obtained through improvements in the existing sampling program. Harvested fish are plentiful enough that more effort could be devoted to obtaining information on the location of harvest. Comparisons of species composition, size, and sex ratio over area and time may provide information to define stocks.

Stock definition could also be addressed through tagging studies. Tagging would be subject to the following difficulties: (1) extremely large numbers of fish must be tagged and recaptured to delineate stocks over large, unconstrained expanses of open ocean, (2) fish brought to the surface from deep water are injured by expansion of the gas bladder, (3) some fishes have high rates of tag shedding (Lai and Culver 1991), and (4) the large vessels required to handle typically rough seas and tag adequate numbers of fish are extremely expensive to operate or charter. Although lingcod can be successfully tagged and released, rockfishes cannot vent their swim bladder and are injured as air in the bladder expands when the fish is brought to the surface. Fish caught in less than 10-20 fathoms (18 m-37 m) can usually be tagged and released (Matthews and Barker 1983; Ayres 1988) but demersal species such as yelloweye rockfish generally inhabit deeper water. A "breakaway tag" has been designed to address tagging difficulties associated with fishes with gas bladders. Evaluation of the technique for use with groundfishes has been limited (O'Connell 1991), but the method would probably work for examining movements provided that large numbers of fish could be tagged. The major drawback in using breakaway tags is the uncertainty in the species composition and the number of fish tagged.

Estimation of sustainable harvest of rockfishes and lingcod will require estimates of relative or absolute abundance. Catch per unit of effort (CPUE) has not performed well as an index of abundance for sedentary species. This is largely due to technological improvements that allow sport and commercial boats to range farther from port and search efficiently for previously unexploited concentrations of fish. For example, decreases in CPUE of yelloweye rockfish in Southeast Alaska underestimated decreases in abundance as boats maintained high catch rates by fishing outward from the major ports (Bracken 1989). One way to address this difficulty would be to collect area-specific harvest and effort data. While CPUE may still not be related to abundance, trends over time and area may provide insight. Again, the current port sampling program might be modified to collect this fishery information without compromising the collection of biological data. Once a significant time series of data is available, catch-at-age analysis could be used to estimate abundance.

Abundance has also been estimated using line transect sampling with a manned submersible. O'Connell et al. (1991) used the method to estimate density of demersal rockfishes on the Fairweather Ground in the Gulf of Alaska. They produced crude estimates of abundance for the entire East Yakutat District by extrapolating the density estimates to the estimated area of similar habitat.

Despite difficulties listed above, tagging studies should be initiated to define stocks of black rockfish and lingcod. Black rockfish decompression stress and injury could be avoided by tagging in shallower waters. Initial studies should address definition of unit stocks by tagging large numbers of fish in all major harvest areas. Once stocks are delineated, appropriate models can be chosen for estimation of abundance, exploitation rate, and other parameters. Studies should be designed to tag fish at various depths and times of year to account for spatial and seasonal movements.

Halibut

The age, size, and sex information gathered in this port sampling program meets or exceeds the current requests of the IPHC. Estimates of halibut harvest are obtained through the statewide postal survey (Mills 1979-1991). As noted earlier, the IPHC is interested in obtaining CPUE data for stock assessment. This project could easily be modified to incorporate collection of catch rate data by modifying the sampling design to gather more robust interview data and sample fewer fish. Data collection should also be modified at some ports to include the location of capture of individual fish whenever possible. Comparisons of age, size, or sex as a function of time and area could provide insight into aspects of life history such as seasonal movements.

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APPENDIX A

Historical Effort and Harvest Estimates

Appendix A1. Southcentral Alaska saltwater angler effort, statewide saltwater angler effort, and total statewide effort (salt water and fresh water) for all species, 1977-1990 (Mills 1979-1991).

Year	Saltwater Effort (angler-days)					South-central Total Effort[e]	Statewide Saltwater Effort	Statewide Effort (fresh and salt water)
	Kenai Peninsula[a]	PWS[b]	Kodiak[c]	Cook Inlet[d]	Alaska Peninsula			
1977	120,842	48,369	14,957	NA[f]	NA	184,168	NA	1,198,486
1978	147,162	35,046	19,063	NA	NA	201,271	NA	1,285,063
1979	143,586	33,939	23,124	NA	NA	200,649	387,558	1,364,739
1980	138,688	31,317	27,646	NA	NA	197,651	404,681	1,488,962
1981	149,842	33,669	29,857	NA	11,828	225,196	435,933	1,420,172
1982	140,200	30,826	41,113	NA	9,075	221,214	467,380	1,623,090
1983	176,710	36,063	40,217	23,346	8,035	284,371	543,383	1,732,528
1984	172,304	40,670	34,213	14,620	10,127	271,934	554,712	1,866,837
1985	174,102	66,291	33,032	6,135	3,035	282,595	565,119	1,943,069
1986	194,593	51,681	31,762	6,199	6,411	290,646	578,027	2,071,412
1987	228,961	69,425	38,671	5,385	7,307	349,749	650,120	2,152,886
1988	233,860	78,367	30,522	6,800	8,222	357,771	675,479	2,311,291
1989	211,427	80,119	35,485	6,495	10,713	344,239	708,028	2,264,079
1990	288,268	98,000	34,969	7,863	15,690	444,790	824,190	2,453,284
Avg:	180,039	52,413	31,045	9,605	9,044	275,446	566,218	1,798,278

[a] All marine waters adjacent to the Kenai Peninsula from Cape Puget to Portage Creek at Portage, including waters around Kalgin Island.

[b] Prince William Sound: all marine waters from Cape Suckling through Prince William Sound to Cape Puget.

[c] All marine waters surrounding the Kodiak and Afognak Island groups, including the Barren and Trinity Islands.

[d] Knik Arm, Turnagain Arm north of Portage, and all marine waters of west Cook Inlet between Knik Arm and Cape Douglas.

[e] Totals prior to 1983 may not include small amounts of marine effort in the Cook Inlet and Alaska Peninsula areas.

[f] Saltwater effort data not available.

Appendix A2. Southcentral Alaska sport halibut harvest and percentage of the statewide total sport halibut harvest, 1977-1990 (Mills 1979-1991).

	Number of Halibut Harvested						Total Statewide Harvest	Percent of Statewide Harvest
Year	PWS[a]	Seward[b]	Cook Inlet[c]	Kodiak[d]	Alaska Pen.[e]	Total		
1977	1,247	1,674	13,497	994	0	17,412	23,244	74.9
1978	933	2,642	25,658	1,721	0	30,954	37,085	83.5
1979	1,691	2,838	27,061	3,013	0	34,603	47,705	72.5
1980	3,143	2,936	30,066	3,651	0	39,796	64,658	61.6
1981	2,495	3,337	38,827	6,858	853	52,370	74,212	70.6
1982	2,735	2,809	39,677	9,180	797	55,198	92,358	59.8
1983	3,493	2,225	60,520	8,545	264	75,047	117,042	64.1
1984	4,428	3,242	61,227	8,179	969	78,045	124,970	62.5
1985	4,527	5,486	63,606	7,303	536	81,458	127,634	63.8
1986	8,331	9,648	85,903	10,960	1,015	115,857	160,885	72.0
1987	4,379	6,520	77,741	9,869	1,596	100,105	145,829	68.7
1988	9,845	11,423	137,525	7,749	1,984	168,526	225,106	74.9
1989	8,697	6,852	127,316	10,435	1,412	154,712	229,016	67.6
1990	10,851	9,278	148,760	9,134	2,545	180,568	247,202	73.0
Mean	4,771	5,065	66,956	6,971	855	84,618	122,639	69.0

[a] Prince William Sound: waters between Cape Suckling and Cape Puget.

[b] Gulf of Alaska waters adjacent to and including Resurrection Bay.

[c] Waters north of a line between Cape Douglas and Point Adam.

[d] Waters surrounding the Kodiak and Afognak Island groups, including the Barren and Trinity Islands.

[e] Waters adjacent to the Alaska Peninsula and Aleutian Islands from Cape Douglas to the mouth of the Naknek River.

Appendix A3. Southcentral Alaska sport rockfish harvest and percentage of the statewide total sport rockfish harvest, 1977-1990 (Mills 1979-1991).

Year	Number of Rockfish Harvested						Total Statewide Harvest	Percent of Statewide Harvest
	PWS[a]	Seward[b]	Cook Inlet[c]	Kodiak[d]	Alaska Pen.[e]	Total		
1977	4,401	12,783	2,098	2,810	0	22,092	31,054	71.1
1978	5,035	17,438	4,981	1,907	0	29,361	46,247	63.5
1979	11,018	21,752	3,518	3,599	0	39,887	70,868	56.3
1980	6,174	27,948	2,014	1,489	0	37,625	79,416	47.4
1981	11,610	19,516	3,585	6,242	421	41,374	87,045	47.5
1982	5,608	22,878	2,627	3,992	178	35,283	86,885	40.6
1983	6,514	17,990	4,710	3,252	62	32,528	82,796	39.3
1984	7,993	22,845	3,640	8,231	1,116	43,825	80,724	54.3
1985	8,853	17,068	2,760	4,691	199	33,571	67,610	49.7
1986	9,762	37,574	7,189	4,479	686	59,690	101,258	58.9
1987	6,563	12,333	3,821	6,501	2,046	31,264	73,528	42.5
1988	12,711	34,906	10,421	11,369	1,875	71,282	128,121	55.6
1989	12,919	24,334	4,694	5,070	255	47,272	86,776	54.5
1990	8,157	18,632	3,305	3,842	2,677	36,613	62,572	58.5
Mean	8,380	22,000	4,240	4,820	680	40,119	77,493	51.8

[a] Prince William Sound: waters between Cape Suckling and Cape Puget.

[b] Gulf of Alaska waters adjacent to and including Resurrection Bay.

[c] Waters north of a line between Cape Douglas and Point Adam.

[d] Waters surrounding the Kodiak and Afognak Island groups, including the Barren and Trinity Islands.

[e] Waters adjacent to the Alaska Peninsula and Aleutian Islands from Cape Douglas to the mouth of the Naknek River.

APPENDIX B

Rockfish Species Composition Data

Appendix B. Species composition of rockfishes landed by sport anglers at Homer, Seward, Whittier, and Valdez in 1991, and at Valdez in 1990.

	Number					Proportion				
Species	Jun	Jul	Aug	Sep	Total	Jun	Jul	Aug	Sep	Total
HOMER										
Black	20	68	46	3	137	0.230	0.342	0.374	1.000	0.333
Brown	0	0	1	0	1	0.000	0.000	0.008	0.000	0.002
Canary	0	0	1	0	1	0.000	0.000	0.008	0.000	0.002
China	0	1	2	0	3	0.000	0.005	0.016	0.000	0.007
Dusky	0	0	28	0	28	0.000	0.000	0.228	0.000	0.068
Quillback	1	0	0	0	1	0.011	0.000	0.000	0.000	0.002
Tiger	1	2	1	0	4	0.011	0.010	0.008	0.000	0.010
Yelloweye	65	128	44	0	237	0.747	0.643	0.358	0.000	0.575
Totals	87	199	123	3	412	1.000	1.000	1.000	1.000	1.000
SEWARD										
Black	127	360	491	148	1126	0.690	0.661	0.661	0.809	0.680
Bocaccio	1	4	5	8	18	0.005	0.007	0.007	0.044	0.011
Canary	0	0	6	2	8	0.000	0.000	0.008	0.011	0.005
China	0	4	3	2	9	0.000	0.007	0.004	0.011	0.005
Copper	0	1	0	0	1	0.000	0.002	0.000	0.000	0.001
Dusky	1	7	11	3	22	0.005	0.013	0.015	0.016	0.013
Pacific Ocean Perch	2	0	0	0	2	0.011	0.000	0.000	0.000	0.001
Quillback	4	21	27	3	55	0.022	0.039	0.036	0.016	0.033
Rosethorn	0	0	2	0	2	0.000	0.000	0.003	0.000	0.001
Rougheye	0	0	4	0	4	0.000	0.000	0.005	0.000	0.002
Silvergray	2	3	1	1	7	0.011	0.006	0.001	0.005	0.004
Tiger	1	5	7	0	13	0.005	0.009	0.009	0.000	0.008
Yelloweye	46	140	183	15	384	0.250	0.257	0.246	0.082	0.232
Yellowtail	0	0	3	1	4	0.000	0.000	0.004	0.005	0.002
Totals	184	545	743	183	1655	1.000	1.000	1.000	1.000	1.000
WHITTIER										
Black	0	0	1	2	3	0.000	0.000	0.020	0.133	0.015
Bocaccio	2	1	0	0	3	0.250	0.008	0.000	0.000	0.015
China	0	3	0	0	3	0.000	0.023	0.000	0.000	0.015
Dusky	0	1	0	0	1	0.000	0.008	0.000	0.000	0.005
Quillback	2	11	13	0	26	0.250	0.084	0.260	0.000	0.127
Silvergray	0	18	3	0	21	0.000	0.137	0.060	0.000	0.103
Yelloweye	4	97	33	13	147	0.500	0.740	0.660	0.867	0.721
Totals	8	131	50	15	204	1.000	1.000	1.000	1.000	1.000

(continued)

Appendix B. (Page 2 of 2).

Species	Number					Proportion				
	Jun	Jul	Aug	Sep	Total	Jun	Jul	Aug	Sep	Total
VALDEZ 1991										
Black	55	148	109	3	315	0.278	0.450	0.354	0.107	0.365
China	1	1	3	1	6	0.005	0.003	0.010	0.036	0.007
Copper	28	32	14	5	79	0.141	0.097	0.045	0.179	0.092
Dusky	11	6	7	1	25	0.056	0.018	0.023	0.036	0.029
Harlequin	1	1	1	0	3	0.005	0.003	0.003	0.000	0.003
Quillback	2	33	77	6	118	0.010	0.100	0.250	0.214	0.137
Redstripe	1	1	0	0	2	0.005	0.003	0.000	0.000	0.002
Rougheye	1	0	0	0	1	0.005	0.000	0.000	0.000	0.001
Sharpchin	0	1	0	0	1	0.000	0.003	0.000	0.000	0.001
Shortraker	0	0	0	1	1	0.000	0.000	0.000	0.036	0.001
Silvergray	0	7	0	1	8	0.000	0.021	0.000	0.036	0.009
Splitnose	3	1	0	0	4	0.015	0.003	0.000	0.000	0.005
Yelloweye	95	98	97	10	300	0.480	0.298	0.315	0.357	0.348
Totals	198	329	308	28	863	1.000	1.000	1.000	1.000	1.000
VALDEZ 1990										
Black	14	16	3	0	33	0.222	0.180	0.056	0.000	0.151
Copper	2	22	11	2	37	0.032	0.247	0.204	0.154	0.169
Dusky	6	4	0	0	10	0.095	0.045	0.000	0.000	0.046
Quillback	6	8	12	2	28	0.095	0.090	0.222	0.154	0.128
Yelloweye	35	39	28	9	111	0.556	0.438	0.519	0.692	0.507
Totals	63	89	54	13	219	1.000	1.000	1.000	1.000	1.000

APPENDIX C

List of Data Filenames and Contents

Appendix C. Names and contents of ASCII computer files containing rockfish, lingcod, and halibut biological data collected in Southcentral Alaska in 1991.

Location	Species	Inclusive Dates	Inclusive Page Numbers	Filename (*.DTA)
Deep Cr.	Halibut	5/26 - 7/29	001-020	10010BA1
	Halibut	8/04 - 9/01	021-028	10010BB1
Homer	Yelloweye rockfish	6/10 - 8/24	001-032	10030BD1
	Black rockfish	6/01 - 9/07	001-022	10030BE1
	Misc. rockfishes	various	various	10030BF1
	Lingcod	6/10 - 8/31	001-025	10030BC1
	Halibut	5/24 - 7/27	001-024	10030BA1
	Halibut	8/02 - 9/08	025-042	10030BB1
Seward	Yelloweye rockfish	6/18 - 9/13	001-053	10020BE1
	Black rockfish	6/18 - 9/13	001-063	10020BG1
	Quillback rockfish	6/22 - 9/07	001-028	10020BF1
	Misc. rockfishes	various	various	10020BH1
	Lingcod	6/18 - 7/29	000-026	10020BB1
	Lingcod	8/02 - 9/14	027-059	10020BD1
	Halibut	6/20 - 7/29	001-023	10020BA1
	Halibut	8/02 - 9/13	024-049	10020BC1
Whittier	Yelloweye rockfish	6/26 - 9/08	001-026	J0020BB1
	Misc. rockfishes and lingcod	various	various	J0020BC1
	Halibut	7/01 - 8/25	001-019	J0020BA1
Valdez	Yelloweye rockfish	6/07 - 7/29	001-027	J0010BB1
	Yelloweye rockfish	8/01 - 9/04	028-047	J0010BI1
	Black rockfish	6/17 - 7/28	001-020	J0010BC1
	Black rockfish	8/02 - 9/01	021-035	J0010BH1
	Quillback rockfish	6/30 - 9/03	001-034	J0010BJ1
	Copper rockfish	6/08 - 9/03	001-020	J0010BK1
	Misc. rockfishes	6/15 - 9/03	various	J0010BL1
	Lingcod	6/16 - 9/01	001-030	J0010BG1
	Halibut	6/09 - 6/30	001-021	J0010BA1
	Halibut	7/01 - 7/29	022-052	J0010BD1
	Halibut	8/01 - 9/04	053-080	J0010BF1